Improving Human Survivability In Aircraft Through Crashworthiness Technology

Huey D. Carden, Senior Researcher
Structures Division
Structural Mechanics Branch
NASA Langley Research Center
Hampton, VA. 23681-0001

Symposium on Enhancing Aircraft Survivability

A Vulnerability Perspective

Naval Post Graduate School
Monterey, CA
October 21-23, 1997

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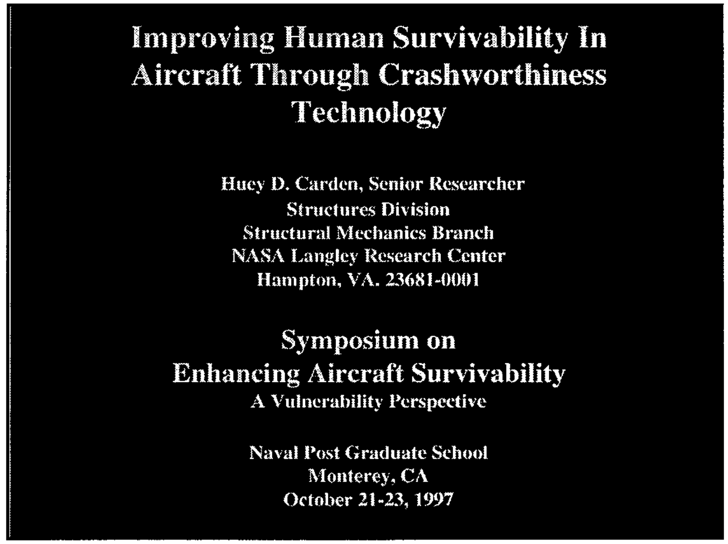
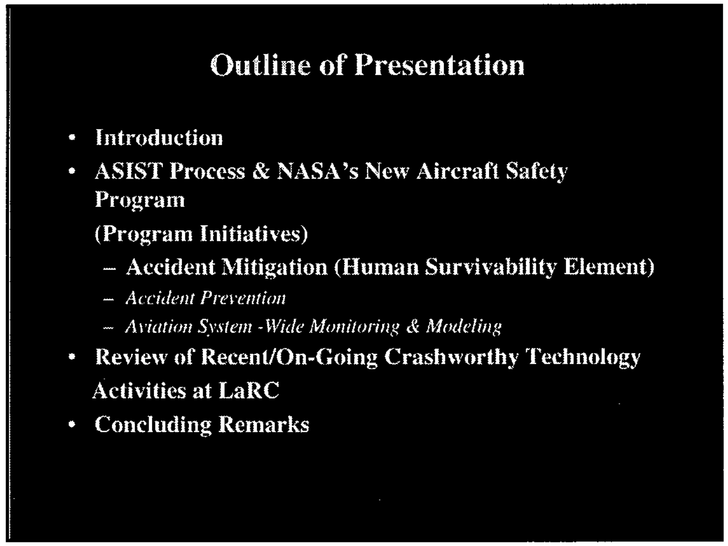
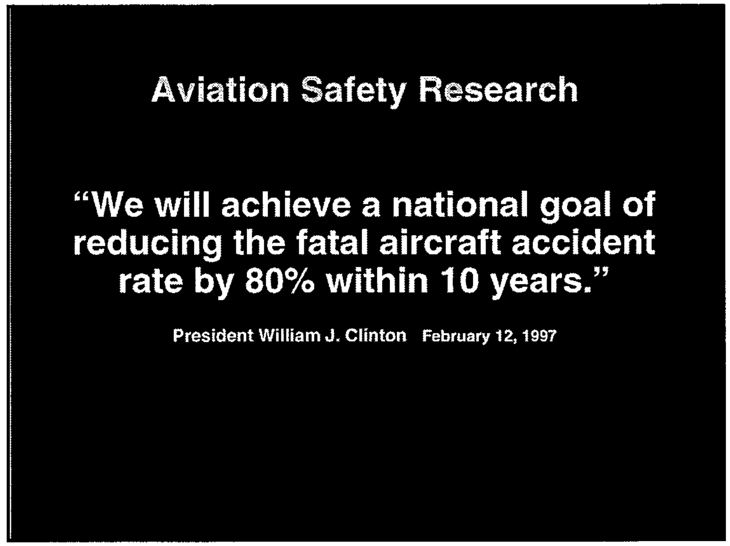


- **My name is Huey Carden. I'm from NASA's Langley Research Center in Hampton, VA.**
- **I'd like to talk a few minutes this morning about Improving Human Survivability in Aircraft Through Crashworthiness Technology.**
- **I believe that Human Survivability is the ultimate goal of Enhancing Aircraft Survivability which is the subject of this Symposium.**



- **I'll try to follow this outline and discuss briefly the ASIST Process (I'll explain this shortly) and the NASA Aircraft Safety Program which has Initiatives Including:**
    - **Accident Mitigation (Human Survivability) which I'll cover, and**
    - **Accident Prevention and System-Wide Monitoring and Modeling which I'll not discuss.**
- **I'll review some recent/ongoing crashworthy technology activities at LaRC that directly support Human Survivability, and**
- **Make a few Concluding Remarks.**



- As many or all of you may know, the President announced in early Februrary the national goal of reducing the fatal aircraft accident rate by 80% in 10 years.

- **As a result of that announcement, NASA committed to supporting that goal and initiated the ASIST process that was the precusor to the formulation of the NASA Aircraft Safety Program (ASP)**

Aviation Safety Investment Strategy Team (ASIST)

Organization:

Tri-Lateral Group: NASA, FAA, DoD

NASA/FAA Coordinating Committee: Bob Whitehead, George Donohue, Guy Gardner,Chris Hart, Neil Planzer

Chair: Charlie Huettner

NASA Code R: Rich Christiansen, Lee Holcomb

FAA: Jan Brecht-Clark, Chuck Hedges, Ava Mims, Chris Seher

DoD: Don Dix

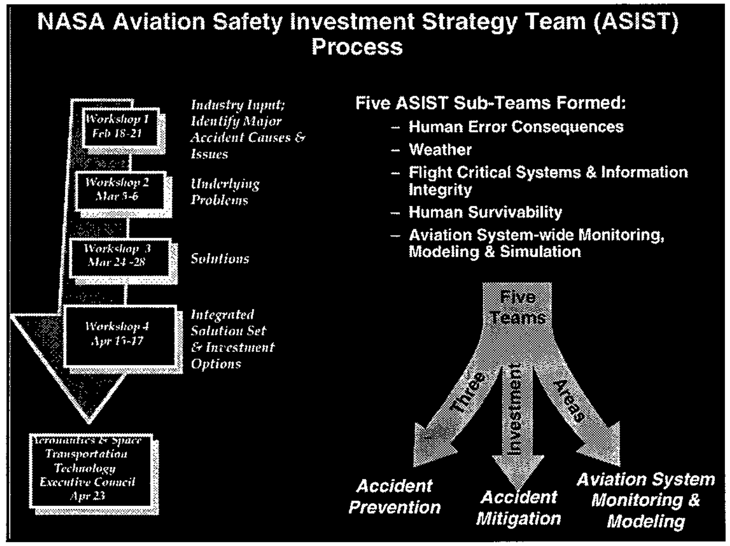
Weather Service: Julian Wright, Susan Zevin

Industry: NASA - AAC, FAA -RE&D Advisory Committee, ITLT

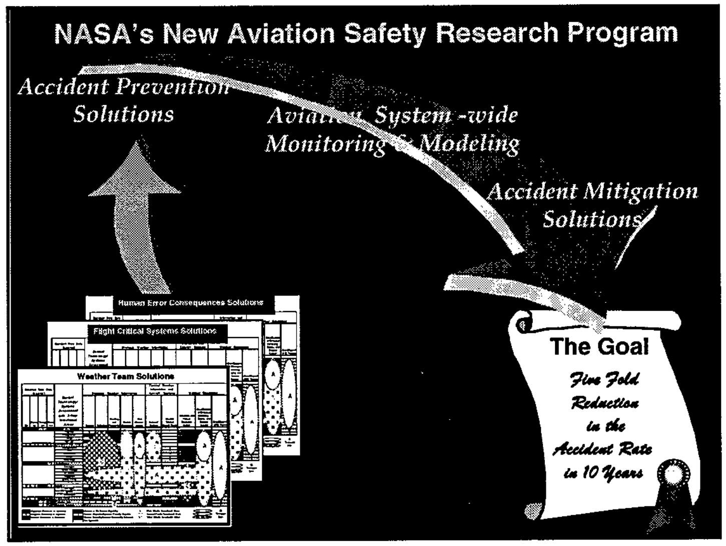
Sub-Team Focus Areas:

- Human Error
- Flight Critical Systems & Information Integrity
- Weather
- Aviation System-wide Monitoring, Modeling & Simulation
- Human Survivability

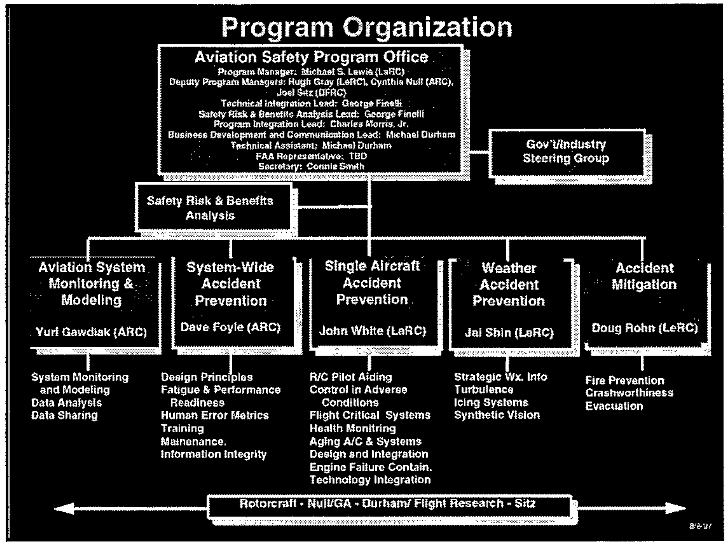
- **ASIST stands for Aviation Safety Investment Strategy Team.**
- **The core group was from NASA, FAA, and DoD.**
- **Chaired by Charlie Huettner of NASA headquarters, Code R FAA, DoD Weather, and Industry reperesenatives as listed completed the core group.**
- **Five focus areas (See List) were to be covered in the ASIST process.**



- **The process involved the formation of 5 sub-teams to focus on the areas : (See List on Right).**
- **I co-chaired the Human Survivability with Gary Frings of the FAA Tech Center.**
- **A series of Workshops were held, the 1st being just 6 days after the President's announcement, followed by three others, culminating in a combined presentation from all five sub-teams to NASA's Aeronautics and Space Transportation Technology Executive Council on April 23rd.**
- **From the 5 areas, 3 investmnent areas were identified : Accident Prevention, Accident Mitigation (Human Survivability), & System-Wide Monitoring).**



- The process used by all the sub-teams was :
    - From statistics (as possible) identify the major (fire, impact, weather, etc) causes of fatalities and serious injuries in accidents,
    - Look for underlying contributors to the major causes, identify potential solutions, assess the current research activities relative to those areas, identify gaps and propose research investments to provide soultions/ improvements in those areas.
- This process led to the 3 potential investment areas addressing safety issues which can help to realize the national goal.
- NASA alone or any other organization alone can not achieve the goal. It will take the combined efforts of many organizations.



- Following the ASIST Process, an RFP was issued to the various NASA Centers to compete which Center would be lead for the new Aircraft Safety Program.
- Langley was selected.
- The Program Organization is shown here with many of the positions filled.
- The 3 Major Investment areas are shown with Prevention (the largest) being composed of the three areas shown, along with the System Monitering and the Accident Mitigation (Human Survivability).
- Cross-cutting representation of Rotorcraft/GA and Flight Testing are included across all investment areas.

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- With respect to the Human Survivability Team, this slide shows the participants with time.
- The numbers grew over the course of the four workshops.

Human Survivability (HS)

Goal:

- The Human Survivability Sub-Team Seeks To Identify, Support, and Develop Solutions To Safety Issues That Can Mitigate and Significantly Reduce The Number of Fatalities and Serious Injuries in Fatal But Survivable Accidents.

Relation To Other Sub-Team Goals:

Commonalties

- Classes of Vehicles Cover General Aviation, Rotorcraft, and Transport.
- Current Assessments of Issues Are Statistically-Driven As Possible.
- Future Assessments Are To Be Scenario-Driven For Future Eras.

Differences:

- The Objective and Metric of the Human Survivability Sub-Team Are the Substantial Reduction of the Number of Fatalities and Serious Injuries, Independent of Fatal Accidents.
- While a Reduction in Fatal Accident Rate Almost Guarantees a Reduction in Absolute Fatality Numbers, The Converse Is Not Necessarily True.
- Fatality Reduction Is Highly Desirable, But Unless Significant "No Fatality" Accidents Results The Fatal Accident Rate May Be Larger Than Desired.

- **The goal of the Human Survivability Team is stated above.**
- **The commonalties in relation to the other sub-teams is also given, however,**
- **A major differences, stressed from the outset, is indicated.**
    - **Human Survivability must focus on reducing the fatalies and serious injuries independent of fatal accidents.**
- **Without 100% success of Human Survivability Technology in reducing the <u>number of fatal accidents</u> (with survivors) to <u>no fatalities status</u>, the fatal aircraft <u>accident rate</u> will not necessarily be reduced as desired.**

Human Survivability

Accident Statistics And Expert Advice Were Used To Guide Planning Efforts And Priority In Human Survivability

Aircraft Category →	Transport World Wide 82-94(14 vr)	Transport World Wide 82-94 (14 vr)
Fatal Accident Area	Number of Accidents	OnBoard Fatalities
Landing	173	290
On-Ground Fire	93	1082
ATC Com.	61	2111
Maint. & Insp.	58	1560
CFIT	49	2890
Loss of Control	45	2632
Ground Ops	33	162
Engine/Crew	21	346
Approach	20	1257
TakeOff Conf.	13	243
Inflight Fire	12	673
Uncontained Engine	13	199

+ Additional Data Mining

+ Expert(s) Advice

1959-90
Accident Data Show:

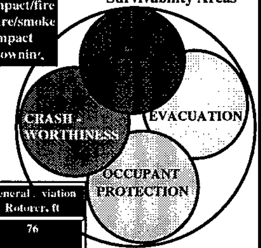
52% Nonsurvivable
3% 1-3 survivors
45% survivable

50% Impact/fire
27% Fire/smoke
18% Impact
5% Drownin,

1985-1995

Aircraft Category ►	General Aviation-All	General . viation Rotorcr. ft
Fatal with at least one survivor	701	76
Accidents with fire	2624	194
Fatal Accidents with fire	1588	101
Total Fatal Accidents	4979	359

Interrelated Human Survivability Areas



Human Survivability (HS)

Challenges/Objective of HS Investments

- Challenges/Objective of Fire Investment :

  To Identify, Support, and Develop Fire Prevention, Detection, and Suppression Concepts That Can Minimize Fire Hazards in Crashes and In-Flight Incidents.

- Challenges/Objective of Crashworthiness Investment:

  To Develop A Systems Approach To Crashworthiness Design That Includes Validated Analysis Methodology, New Structural Concepts And Materials, Safer Cabin Interiors Design, Advanced Restraint Equipment, Design And Injury Criteria To Enhance Crash Safety.

- Challenges/Objective of Evacuation Investment :

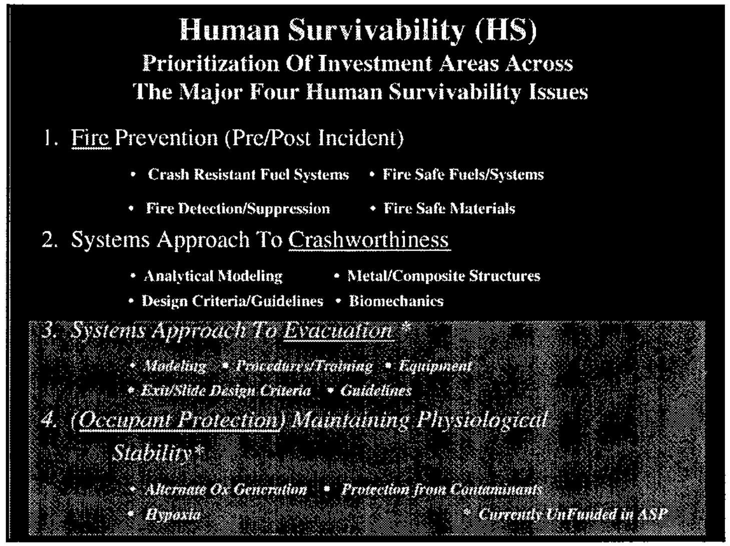
  To Develop A Systems Approach For Evacuation That Includes Analysis/ Simulation Methodology, New Procedures ,Training, Equipment, And Design Criteria Which Can Enhance And Provide Means For More Timely Evacuation During Fire In Aircraft Accidents.

- Challenges/Objective of Occupant Protection Investment:

  To Develop Detection/Warning Means, New Procedures ,Training, And Equipment Which Can Provide Occupant Protection From Fire Related Hazards And Thus Provide Additional Evacuation Time.

All the Challenges/Objectives Are Aimed At Mitigation/Reduction of Fatalities and Serious Injuries In Current As Well As New Aircraft Configurations.

- **The challenges and objectives of the four major potential investment areas are stated above.**



- **The Prioritized Investment Areas are shown here with Fire Prevention and Systems Approach to Crashworthiness being the number 1 and 2 priority areas.**
- **3rd priority is Systems Approach to Evacuation -- on the "bubble" for potential funding, and**
- **Occupant Protection is the 4th priority area.**
- **These Investment areas were included in the sum total of the other sub-team findings and recommendations, all of which were also prioritized by the entire ASIST team.**
- **Evacuation and Occupant Protection are not currently included in the program due to funding limitations and priority.**

Planning Workshops

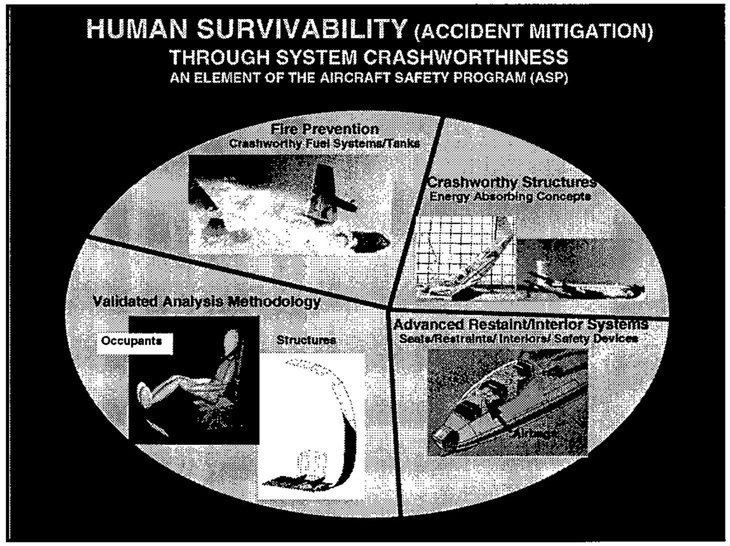
Near Term Timeline

- Industry Brief 8/97
- Detailed Planning Workshops 9/97-12/97
- Early Activities Initiated 10/97 - 12/97
- Prepare/Issue NASA Research Announcement (or equivalent) - 11/97-2/98
- Proposals Due - 1/98 - 3/98
- Proposals Reviewed - 2/98 - 5/98
- New Starts Initiated 4/98 - 10/98

Initial Workshop Subjects

- Data Analysis/Data Monitoring Data Sharing
- Health Monitoring
- Strategic Weather Information
- Aging Aircraft/Systems
- **Fire Prevention (July-Dec)**
- **Crashworthiness (July-Dec)**
- Synthetic Vision
- Rotorcraft Pilot Aiding
- Training
- Control in Adverse Conditions
- Information Integrity
- Flight Critical Systems
- Human Error

- **Planning workshops on the various subjects listed above have been and are on-going to plan program activities in the investment areas across the entire ASIST spectrum.**
- **Fire and Crashworthiness activities began in July and will continue through December for laying out the efforts in 98 and beyond.**
- **The next Crashworthiness workshop is planned for December 8 - 9, 1997 at Langley Research Center.**



- Thus, in summary, Human Survivability (Accident Mitigation) through Systems Approach to Crashworthiness is an element of the New NASA Aircraft Safety Program.
- Areas of the Crashworthiness Focus Include a Fire Prevention Element, Energy Absorbing Crashworthy Structures, Interiors and Safety Restraint Systems, and Validated Structural and Occupant Analysis & Modeling
- All these activities are aimed at enhancing Human Survivability through Crashworthiness Technology.

At This Point I'd Like to Turn To Examples of Some Recent/Ongoing Research at LaRC Directly Related to the Crashworthy Technology Areas in NASA's New Aircraft Safety Program (ASP)

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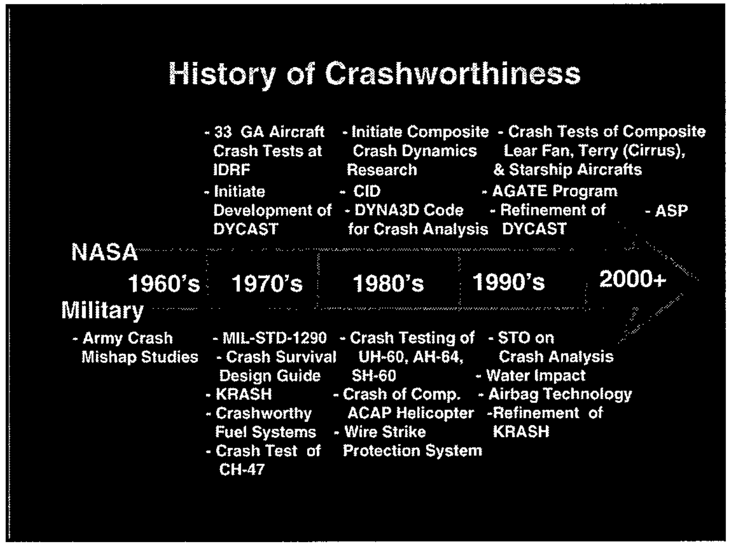
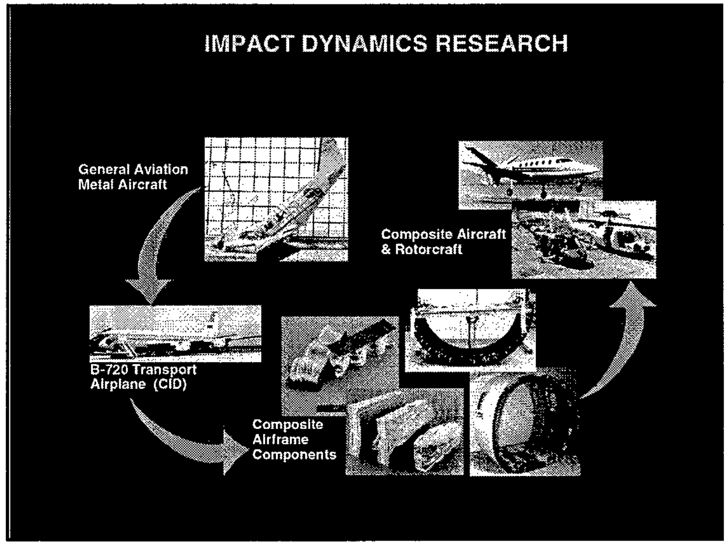
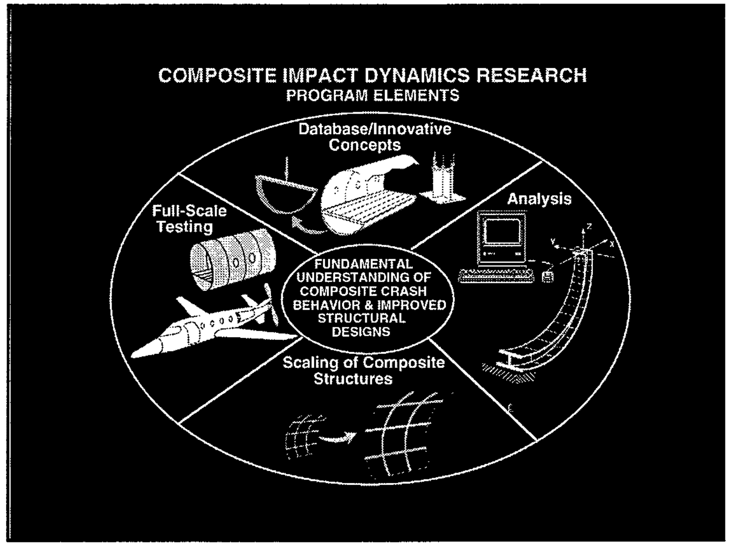


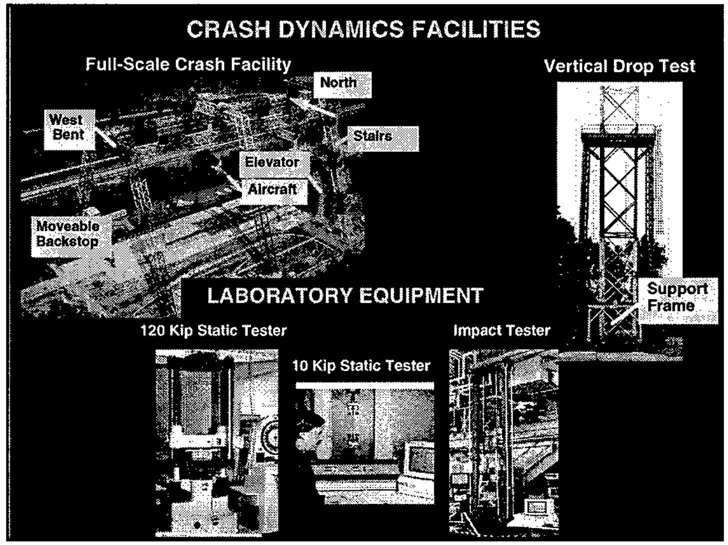
- **Some of the major activities in crashworthiness research by NASA LaRC is illustrated along with Army focuses which has involved our support with full-scale tests of helicopter safety systems such as wire strike systems, airbags, fuel cells, etc.**
- **Our involvement goes back to the late 60's with the start of the GA metal aircraft crash test program and analytical development of computer tool.**
- **Shift to transport emphasis occurred with CID in mid 80's.**
- **Parallel to CID was beginning of focus on composite structures for aircraft.**
- **In the 90's we have tested composite aircraft under crash loads to build database and now the 00's hold the new Aircraft Safety Program efforts.**



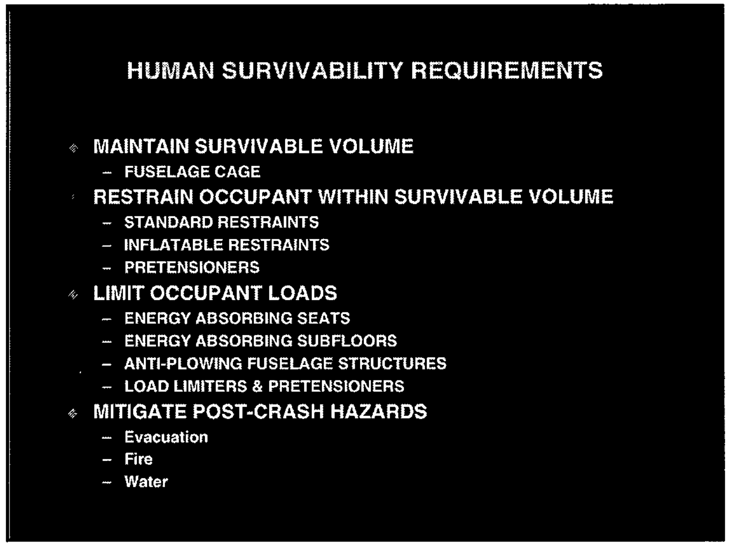
- **This is a pictorial representation of the data on the previous slide showing the progression of LaRC efforts in Crashworthiness for enhancing human survivability.**
- **It shows the GA metal aircraft work, the shift to transport emphasis with CID, and paralleling that the movie into composite structures and full-scale composite aircraft efforts.**



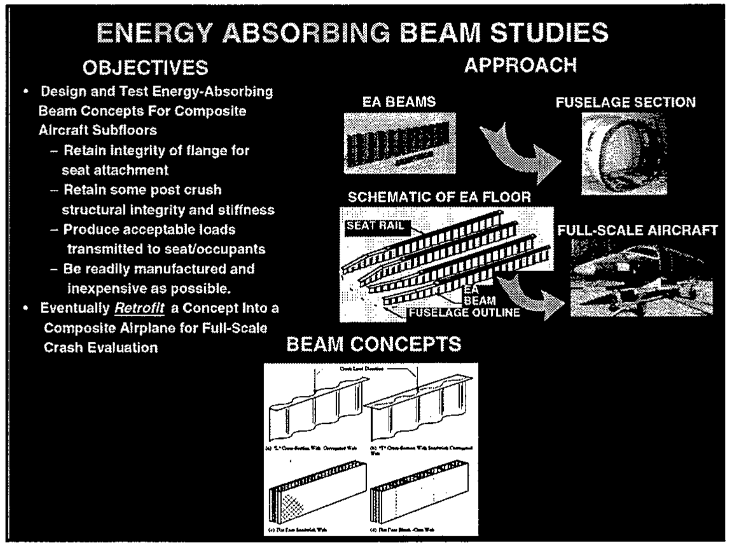
- **The elements of the Composite Impact Dynamics efforts are shown above.** 250
- **The elements include database and innovative concepts, companion analysis, scaling studies for potential relief from full-scale structural requirements, and the full-scale testing where possible.**
- **All the efforts are aimed at developing a fundamental understanding of composite structures behavior under crash loads and the development of improved design to enhance human survivability through crashworthiness technology.**



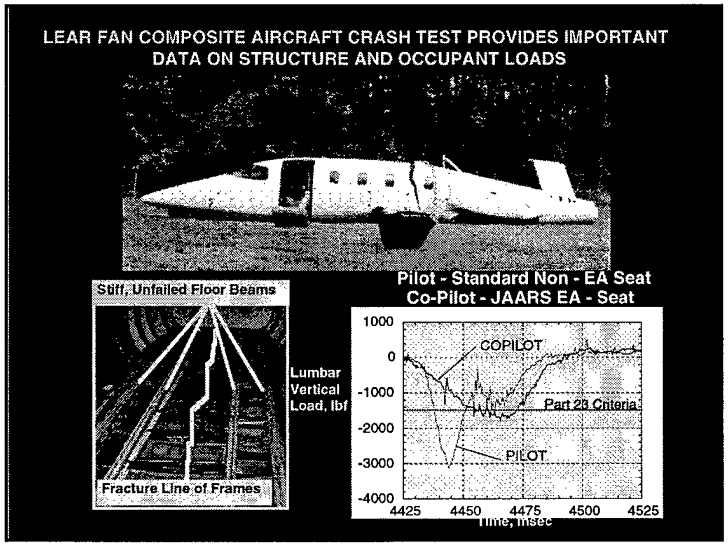
- Facilities at LaRC for use in Crashworthiness Technology efforts are shown.
- We have a full-scale crash facility (Former Lunar Landing Facility for training astronauts for moon landing) converted in late 60's to do full-scale aircraft crash tests.
- Facility is a 240' high, 400' long gantry under which we suspend fully instrumented test articles (up to 40,000 lbm) for crash testing under controlled conditions.
- We also have a vertical drop facility under one leg of the gantry for vertical tests up to 707 cross-section size.
- Various static test equipment is use in the lab for components testing, and an Impact Tower is available for dynamics component tests.
- Data acquisition and analysis is done on a computer based system.



- **Whenever an effort is undertaken in crashworthiness it should address some aspect of the requirements for Human Survivablity.**
- **Those requriements are:**
    - **Maintain livable volume**
    - **Restraint the occupant within the volume**
    - **Limit the loads to the occupant**
    - **Minimize the post crash hazards**
- **The next few slides illustrate some of our efforts.**



- A particular effort which involves the element level, the component level and the full-scale level is an Energy Absorbing Beam Study.
- Objectives of the study are listed above left. Approach is illustrated at the right.
- Various composite beam concepts (bottom center) are being designed, fabricated, and tested, both statically and dynamically.
- Aircarft sections (component level) when possible are modified for evaluation with EA beam concepts.
- A down-select will be made for incorporation into a full-scale aircraft for evaluation of crash performance.



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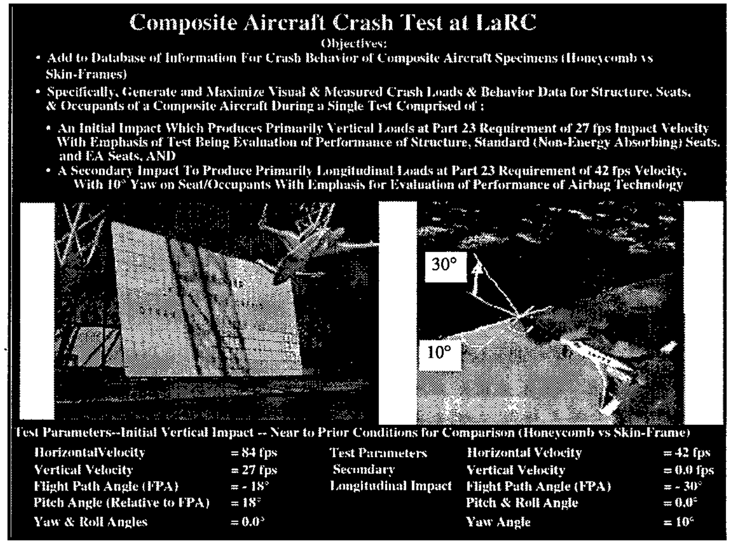
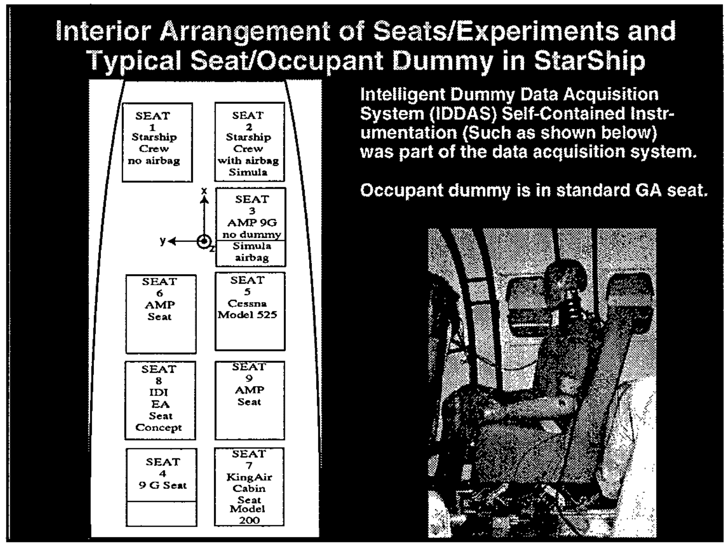
- Part of the impetus for the EA beam work of the previous slide is shown here.
- A full-scale LearFan composite skin-frame construction aircraft was crash tested for database information and crash evaluation.
- The test was a flat impact at 31 fps vertical, 84 fps longitudinally.
- High g loads (250 g's, 7-8 msec) at the floor/seat attachments lead to excessive occupant loads.
- Failure was fracturing of all the composite frames along the bottom of the aircraft floor region. No failure occurred in the metal floor beams beneath the seat rails.
- Pilot spinal load in non-EA seat was over 3000 lbf while the co-pilot in a JAARS EA concept was slightly over the Part 23 requirement of 1500 lbf.

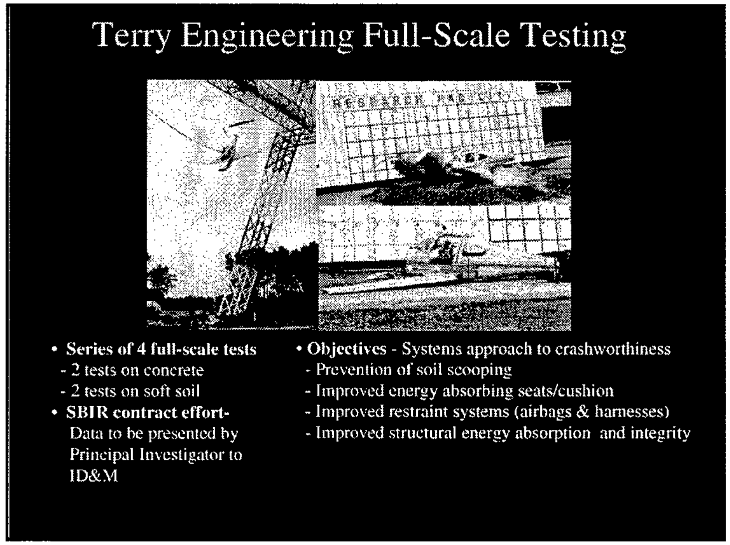


- **Additional crash testing of a honeycomb construction for comparison to the skin-frame of the Lear has been conducted.**
- **Test was designed to give:**
    - **Initial flat impact 27 fps vertical 84 fps longitudinal (close to previous Lear parameters) for primary vertical loads to evaluate structure, seats and restraints performance,**

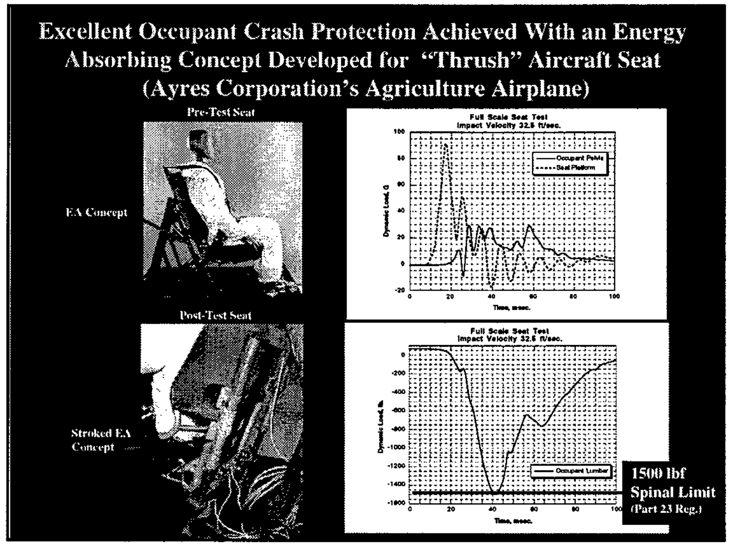
      and
    - **A secondary test with longitudinal inputs at 42 fps, 10 degree yaw into an dirt embankment for airbag technology assessment.**



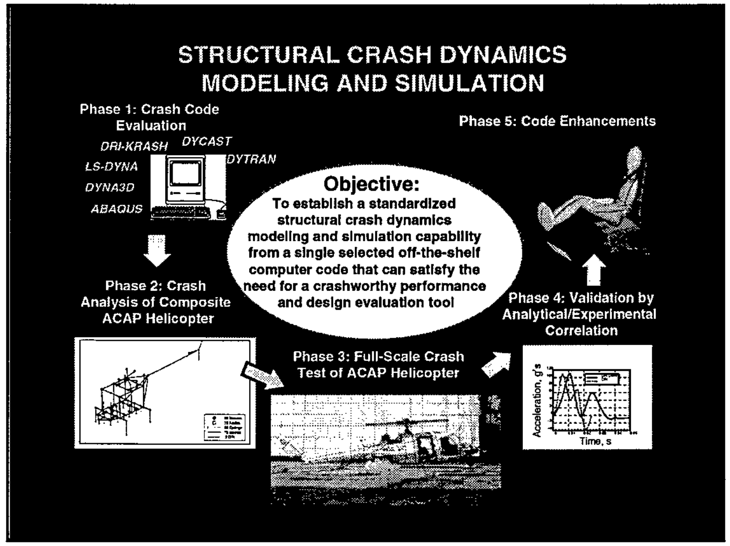
- Interior seating arrangement (EA and standard), and airbag set-up are shown above.
- Right figure shows one of the self-contained instrumented dummy occupants used along with our own instrumented occupant dummies.
- Cockpit airbag was in co-pilot position beside pilot without airbag.
- A standard 9 g seat with airbag on back was in front of occupied position for testing empty seat situation.
- Other standard seats from a manufacturer a second EA seat concept were on-board.



- **We have also conducted 4 other composite aircraft crash tests supporting a SBIR effort by Terry Engineering and Cirrus Design.** 257
- **Two tests were onto concrete and two were into soft soil.**
- **Objectives are listed above.**
- **Data are being shared with the AGATE Integrated Design and Manufacturing Work Package members.**
- **AGATE's ID&M has a major crashworthiness element in that program.**



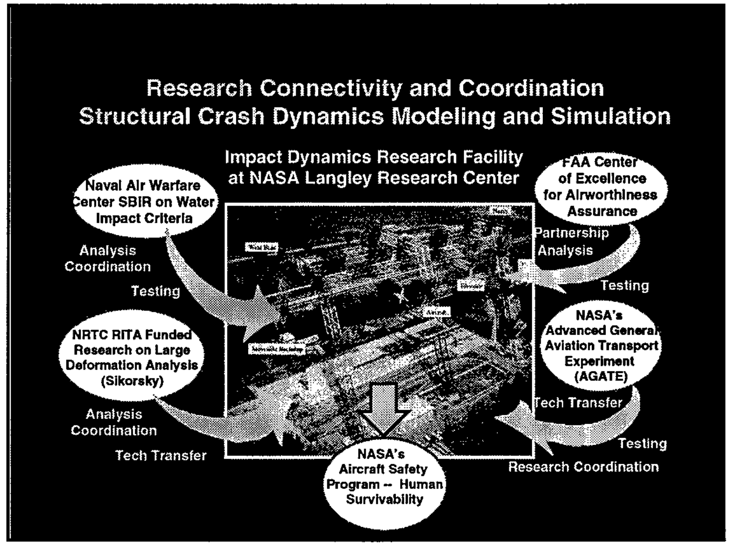
- An activity with EA seat application for enhancing human survivablity is shown here.
- Existing aircraft seat for an agriculture aircraft was modified to include EA concept that if it failed to operate was no worse than the original seat performance.
- Minimial weight added (weight was not a critical factor).
- Tested at 32.5 fps vertical impact velocity, with resulting peak of 90 g's approximately 20 msec duration applied to seat attachment points.
- G's on occupant were about 15 g's, but more importantly the compressive spinal load at 32. 5 fps did not exceed 1500 lbf Part 23 requirement at a lower impact velocity !
- Technology information has been transfered to Ayres Corporation for whatever they wish to do with approach and concept.



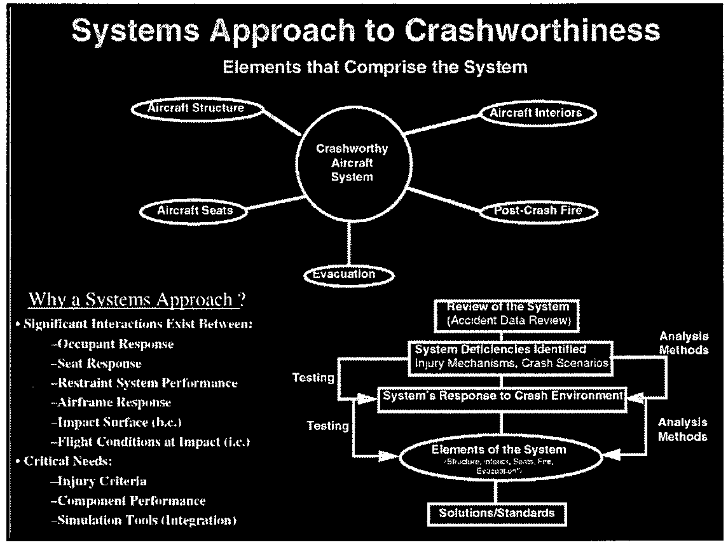
- In terms of Analytical Modeling and Simulation, Army personnel co-located at the facility are involved in an effort :

  To establish a standardized structural crash dynamics modeling and simulation capability from a single selected off-the-shelf computer code that can satisfy the need for a crashworthy performance and design evaluation tool.

- Several codes are being evaluated before a down-select with which an ACAP helicopter will be analyzed.
- Follow-on efforts will be to crash test an ACAP article (similar to one shown), compare the analytical/experimental results and make recommendations for code improvements as necessary.



- This effort is being well coordinated with various, intereted organization (see ovals above).
- The effort ties in well with helping to achieve the overall goal of the Human Survivability or Crashworthiness element in the NASA Aircraft Safety Program.



- **A Systems Approach to Crashworthiness to Enhance Human Survivability in aircraft has been emphasized in this presentation.**
- **If, as shown in the top circle, we want to have a crashworthy aircraft, all the elements that comprise that system must be considered as a system.**
- **Why ? Because (bottom left), interactions occur among all the elements that comprise the aircraft, structure, the seats, the restraints, the occupant, & the impact conditions.**
- **Thus (bottom right), a systematic approach of identifying the system, the scenarios, the response of the elements of the system, and using combined test and analysis methods are necessary to develop solutions and standards for designing crashworthy technology into aircraft for Enhancing Human Survivability.**

Concluding Remarks

- A Brief Review Was Given of the ASIST Process and Planning for NASA's New Aircraft Safety Program (ASP).
- During the ASIST Process, Against An Assessment of Expected Big Pay- off Areas for Reducing Fatalities and Serious Injuries In Fatal But Survivable Aircraft Accidents, The Human Survivability SubTeam :
    - Identified Four Major Focus Areas for Potential Investments Involving Survivability Initiatives.
    - Proposed A Priority List of Efforts and Allocations Within Areas.
- Planning (Both In Base and the Focused Program) Is Underway Which Supports Human Survivability Initiatives Involving Crashworthiness Technologies.
- NASA LaRC Has Been and Still Is Involved With Aircraft Research to Enhance Human Survivability Through Crashworthiness Technology.
- A Brief Review Was Given of Recent/Ongoing Crashworthiness Research at LaRC For Enhancing Human Survivability.
- Leveraging and Building on Existing Human Survivability Technology Efforts To Achieve The Aircraft Safety Program Goals Is a Strategy of The New NASA Program.

- **Concluding comments are listed above.**
- **Note that NASA Langley Research Center has been and still is involved with crashworthy technology which is aimed at enhancing human survivability.**
- **The new NASA Aircraft Safety Program element in Crashworthiness is leveraging and building upon these efforts as part of the program strategy.**

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Hampton, VA. 23681-0001

Symposium on Enhancing Aircraft Survivability

A Vulnerability Perspective

Naval Post Graduate School
Monterey, CA
October 21-23, 1997

Outline of Presentation

- Introduction
- ASIST Process & NASA's New Aircraft Safety Program

  (Program Initiatives)
  - Accident Mitigation (Human Survivability Element)
  - *Accident Prevention*
  - *Aviation System -Wide Monitoring & Modeling*
- Review of Recent/On-Going Crashworthy Technology Activities at LaRC
- Concluding Remarks

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Aviation Safety Research

"We will achieve a national goal of reducing the fatal aircraft accident rate by 80% within 10 years."

President William J. Clinton   February 12, 1997

ASIST Process and Planning for NASA's New Aircraft Safety Program (ASP)

Aviation Safety Investment Strategy Team (ASIST)

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Industry: NASA - AAC, FAA -RE&D Advisory Committee, ITLT

Sub-Team Focus Areas:

- » Human Error
- » Flight Critical Systems & Information Integrity
- » Weather
- » Aviation System-wide Monitoring, Modeling & Simulation
- » Human Survivability

NASA Aviation Safety Investment Strategy Team (ASIST) Process

Workshop 1
Feb 18-21 — *Industry Input; Identify Major Accident Causes & Issues*

Workshop 2
Mar 5-6 — *Underlying Problems*

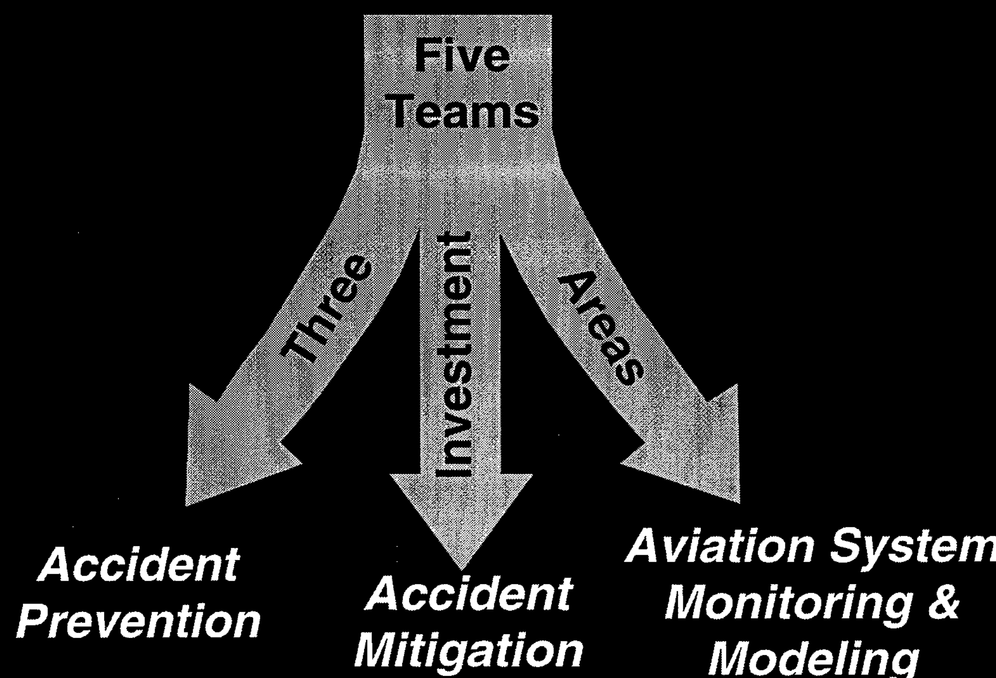
Workshop 3
Mar 24 -28 — *Solutions*

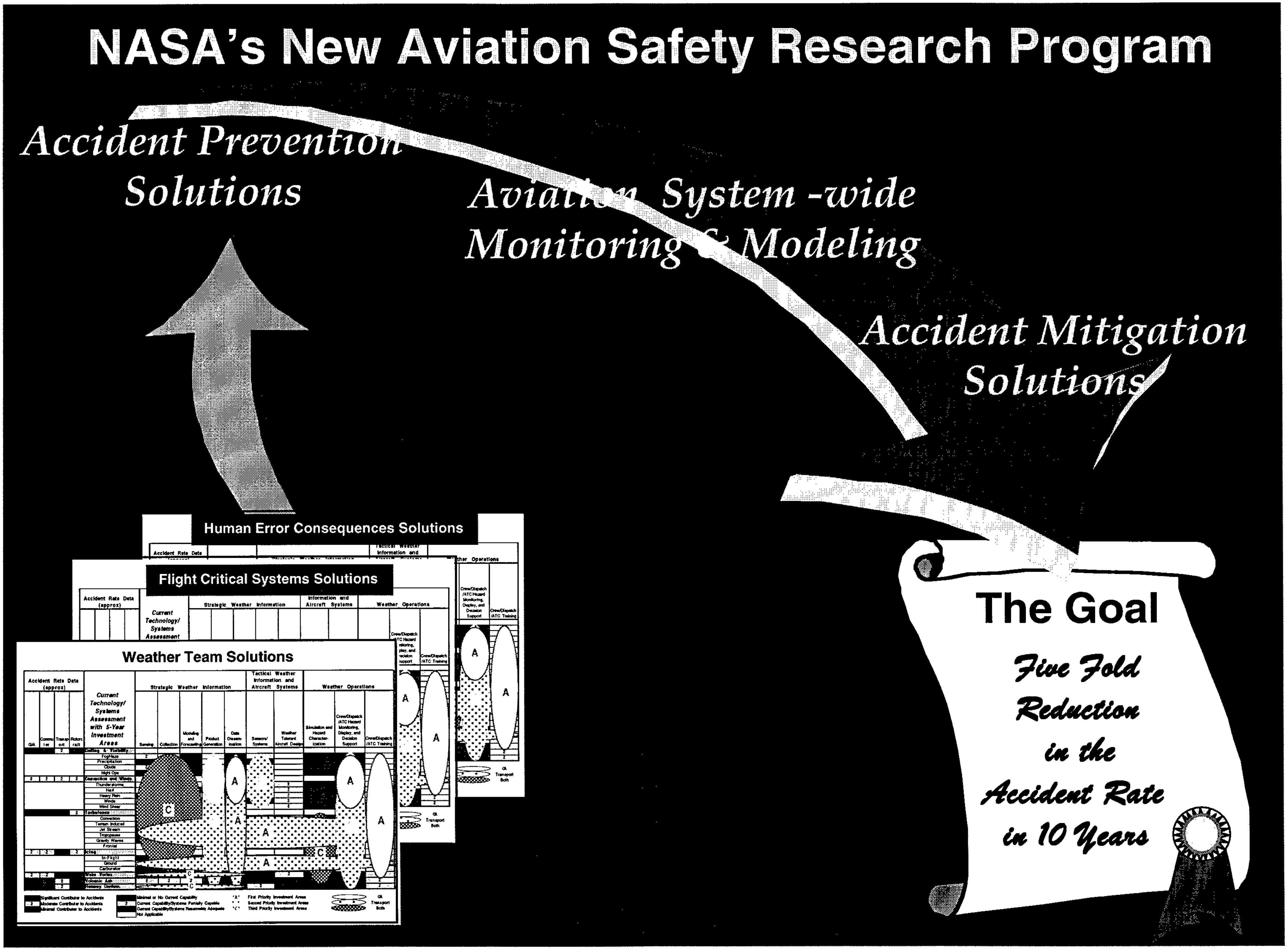
Workshop 4
Apr 15-17 — *Integrated Solution Set & Investment Options*

Aeronautics & Space Transportation Technology Executive Council Apr 23

Five ASIST Sub-Teams Formed:

- Human Error Consequences
- Weather
- Flight Critical Systems & Information Integrity
- Human Survivability
- Aviation System-wide Monitoring, Modeling & Simulation




NASA's New Aviation Safety Research Program
Accident Prevention Solutions
Aviation System -wide Monitoring & Modeling
Accident Mitigation Solutions
Human Error Consequences Solutions
Flight Critical Systems Solutions
Weather Team Solutions
The Goal
Five Fold Reduction in the Accident Rate in 10 Years

Program Organization

Aviation Safety Program Office

Program Manager: Michael S. Lewis (LaRC)
Deputy Program Managers: Hugh Gray (LeRC), Cynthia Null (ARC), Joel Sitz (DFRC)
Technical Integration Lead: George Finelli
Safety Risk & Benefits Analysis Lead: George Finelli
Program Integration Lead: Charles Morris, Jr.
Business Development and Communication Lead: Michael Durham
Technical Assistant: Michael Durham
FAA Representative: TBD
Secretary: Connie Smith

Gov't/Industry Steering Group

Safety Risk & Benefits Analysis

Aviation System Monitoring & Modeling

Yuri Gawdiak (ARC)

- System Monitoring and Modeling
- Data Analysis
- Data Sharing

System-Wide Accident Prevention

Dave Foyle (ARC)

- Design Principles
- Fatigue & Performance Readiness
- Human Error Metrics
- Training
- Mainenance.
- Information Integrity

Single Aircraft Accident Prevention

John White (LaRC)

- R/C Pilot Aiding
- Control in Adverse Conditions
- Flight Critical Systems
- Health Monitring
- Aging A/C & Systems
- Design and Integration
- Engine Failure Contain.
- Technology Integration

Weather Accident Prevention

Jai Shin (LeRC)

- Strategic Wx. Info
- Turbulence
- Icing Systems
- Synthetic Vision

Accident Mitigation

Doug Rohn (LeRC)

- Fire Prevention
- Crashworthiness
- Evacuation

Rotorcraft - Null/GA - Durham/ Flight Research - Sitz

8/8/97

Human Survivability Team (In Time)
Attendance

Workshop 1-- February 19-21, 1997

Name	Organization
Huey Carden	NASA LaRC
LTC Bruce Bailey	DoD Army
Dr. James Hicks	DoD Army Safety Center
Van Gowdy	FAA/CAMI
Dick Hill	FAA Tech Center
Gus Sarkos	FAA Tech Center
Jerry Hordinsky	FAA/CAMI
Gary Frings	FAA-TC

Workshop 2 -- March 6 -7, 1997

Bill Shook	Douglas Aircraft
Mike Norman	McDonnell Douglas
George Neat	DOT Volpe Center
Ron Welding	ATA
Jim Hicks	Army Safety Center
Huey Carden	NASA LaRC
Mike Downs	FAA/ACE
Jeff Marcus	FAA/CAMI
Jerry Hordinsky	FAA/CAMI
Gary Frings	FAA-TC

Workshop 3 -- March 24 -28, 1997

Diane Sandwick	Boeing Payloads
Todd Curtis	Boeing Airplane Safety Eng.
Bill Shook	Douglas Aircraft Cabin Safety
Steve Hooper	WSU-NIAR
George Neat	DOT Volpe Center
Ronda Ruderman	Assn. of Flight Attendants
RaNae Contarino	NAWC Pax
Gregory Feith	NTSB-DCA
Huey Carden	NASA LRC
Jeff Marcus	FAA/CAMI

Workshop 3 -- March 24 -28, 1997

Name	Organization
Stephen Soltis	FAA Resource Specialist
Gary Frings	FAA-TC
Robert Friedman	NASA LeRC

Workshop 4 -- April 15-17,1997

Name	Organization
Bruce Holmberg	ARCCA
Christopher Witkowski	Assoc. Flight Attendants
Maynard M. Foster	Assoc. Flight Attendants
Dr. Jonathan Kaufman	DoD NAWCAD
Paul Kinzay	DoD Naval Safety Center
Ric Loeslien	DoD NAWCAD
RaNae Contarino	DoDNAWCADPax
Martin Lentz	DoD UASF-WL/FIVS
George Neat	DOT/Vople Center
Gary Frings	FAA TC
Jeff Marcus	FAA/CAMI
Jerry Hordinsky	FAA/CAMI
Bill Shook	McDonnell Douglas
Huey Carden	NASA LaRC
Howard Ross	NASA LeRC
David Myres	NAVMAR
Maria Thorpe	NAWCAD Pax
Matt McCormick	NTSB

Human Survivability (HS)

Goal:

- **The Human Survivability Sub-Team Seeks To Identify, Support, and Develop Solutions To Safety Issues That Can Mitigate and Significantly Reduce The Number of Fatalities and Serious Injuries in Fatal But Survivable Accidents.**

Relation To Other Sub-Team Goals:

Commonalties

- **Classes of Vehicles Cover General Aviation, Rotorcraft, and Transport.**
- **Current Assessments of Issues Are Statistically-Driven As Possible.**
- **Future Assessments Are To Be Scenario-Driven For Future Eras.**

Differences:

- **The Objective and Metric of the Human Survivability Sub-Team Are the Substantial Reduction of the Number of Fatalities and Serious Injuries, Independent of Fatal Accidents.**
- **While a Reduction in Fatal Accident Rate Almost Guarantees a Reduction in Absolute Fatality Numbers, The Converse Is Not Necessarily True.**
- **Fatality Reduction Is Highly Desirable, But Unless Significant "No Fatality" Accidents Results The Fatal Accident Rate May Be Larger Than Desired.**

Human Survivability

Accident Statistics And Expert Advice Were Used To Guide Planning Efforts And Priority In Human Survivability

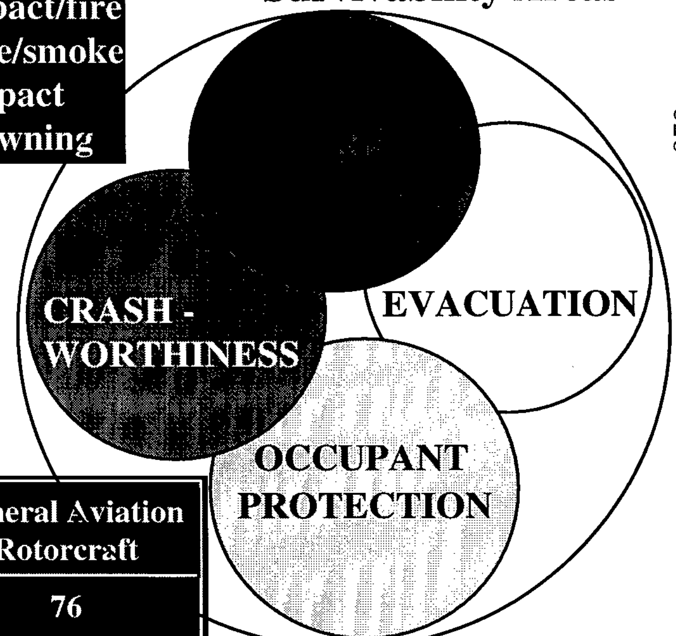
Aircraft Category →	Transport World Wide 82-94(14 yr)	Transport World Wide 82-94 (14 yr)
Fatal Accident Area	Number of Accidents	OnBoard Fatalities
Landing	173	290
On-Ground Fire	93	1082
ATC Com.	61	2111
Maint. & Insp.	58	1560
CFIT	49	2890
Loss of Control	45	2632
Ground Ops	33	162
Engine/Crew	21	346
Approach	20	1257
TakeOff Conf.	13	243
Inflight Fire	12	673
Uncontained Engine	13	199

1959-90

Accident Data Show:

52% Nonsurvivable **50% Impact/fire**
3% 1-3 survivors **27% Fire/smoke**
45% survivable **18% Impact**
5% Drowning

Interrelated Human Survivability Areas



273

1985-1995

Aircraft Category →	General Aviation-All	General Aviation Rotorcraft
Fatal with at least one survivor	701	76
Accidents with fire	2624	194
Fatal Accidents with fire	1588	101
Total Fatal Accidents	4979	359

+ Additional Data Mining

+ Expert(s) Advice

Human Survivability (HS)

Challenges/Objective of HS Investments

- Challenges/Objective of Fire Investment :

  To Identify, Support, and Develop Fire Prevention, Detection, and Suppression Concepts That Can Minimize Fire Hazards in Crashes and In-Flight Incidents.

- Challenges/Objective of Crashworthiness Investment:

  To Develop A Systems Approach To Crashworthiness Design That Includes Validated Analysis Methodology, New Structural Concepts And Materials, Safer Cabin Interiors Design, Advanced Restraint Equipment, Design And Injury Criteria To Enhance Crash Safety.

- Challenges/Objective of Evacuation Investment :

  To Develop A Systems Approach For Evacuation That Includes Analysis/ Simulation Methodology, New Procedures ,Training, Equipment, And Design Criteria Which Can Enhance And Provide Means For More Timely Evacuation During Fire In Aircraft Accidents.

- Challenges/Objective of Occupant Protection Investment:

  To Develop Detection/Warning Means, New Procedures ,Training, And Equipment Which Can Provide Occupant Protection From Fire Related Hazards And Thus Provide Additional Evacuation Time.

All the Challenges/Objectives Are Aimed At Mitigation/Reduction of Fatalities and Serious Injuries In Current As Well As New Aircraft Configurations.

Human Survivability (HS)

Prioritization Of Investment Areas Across The Major Four Human Survivability Issues

1. Fire Prevention (Pre/Post Incident)
   - **Crash Resistant Fuel Systems**
   - **Fire Safe Fuels/Systems**
   - **Fire Detection/Suppression**
   - **Fire Safe Materials**
2. Systems Approach To Crashworthiness
   - **Analytical Modeling**
   - **Metal/Composite Structures**
   - **Design Criteria/Guidelines**
   - **Biomechanics**
3. *Systems Approach To Evacuation* *
   - ***Modeling***
   - ***Procedures/Training***
   - ***Equipment***
   - ***Exit/Slide Design Criteria***
   - ***Guidelines***
4. *(Occupant Protection) Maintaining Physiological Stability**
   - ***Alternate Ox Generation***
   - ***Protection from Contaminants***
   - ***Hypoxia***

****** Currently UnFunded in ASP***

Planning Workshops

Near Term Timeline

- Industry Brief 8/97
- Detailed Planning Workshops 9/97-12/97
- Early Activities Initiated 10/97 - 12/97
- Prepare/Issue NASA Research Announcement (or equivalent) - 11/97-2/98
- Proposals Due - 1/98 - 3/98
- Proposals Reviewed - 2/98 - 5/98
- New Starts Initiated 4/98 - 10/98

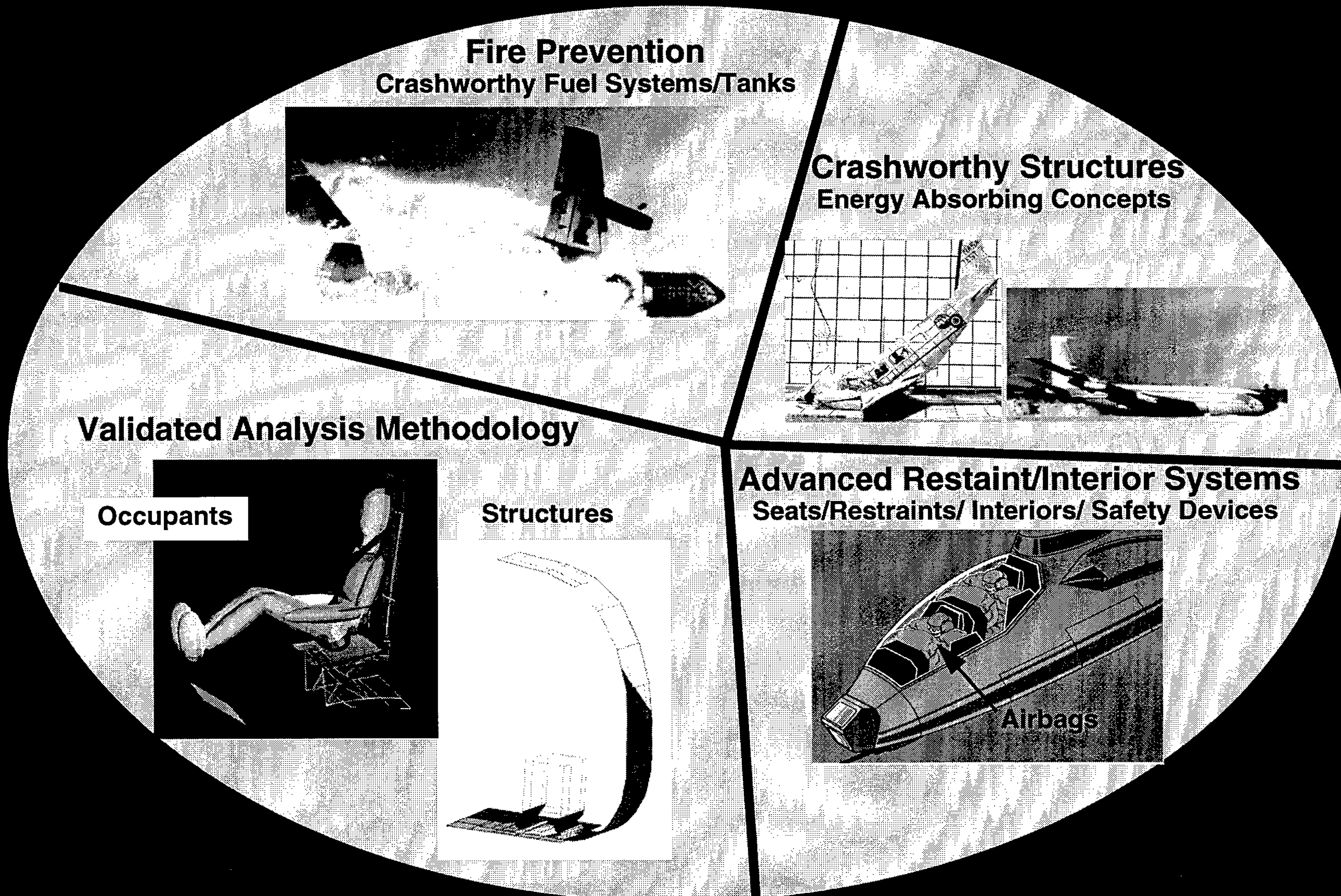
Initial Workshop Subjects

- Data Analysis/Data Monitoring Data Sharing
- Health Monitoring
- Strategic Weather Information
- Aging Aircraft/Systems
- **Fire Prevention (July-Dec)**
- **Crashworthiness (July-Dec)**
- Synthetic Vision
- Rotorcraft Pilot Aiding
- Training
- Control in Adverse Conditions
- Information Integrity
- Flight Critical Systems
- Human Error

HUMAN SURVIVABILITY (ACCIDENT MITIGATION)

THROUGH SYSTEM CRASHWORTHINESS

AN ELEMENT OF THE AIRCRAFT SAFETY PROGRAM (ASP)



At This Point I'd Like to Turn To Examples of Some Recent/Ongoing Research at LaRC Directly Related to the Crashworthy Technology Areas in NASA's New Aircraft Safety Program (ASP)

History of Crashworthiness

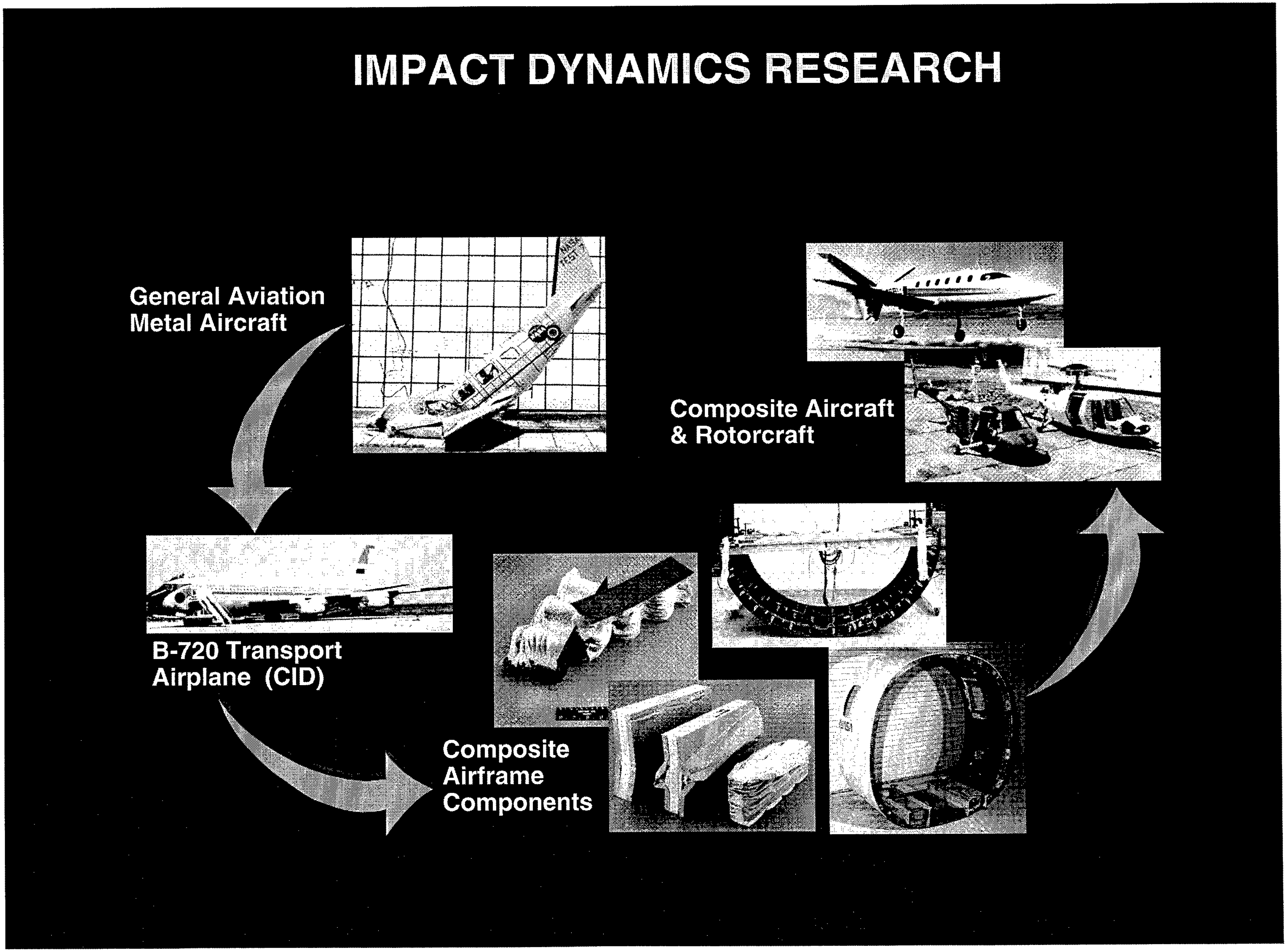
NASA

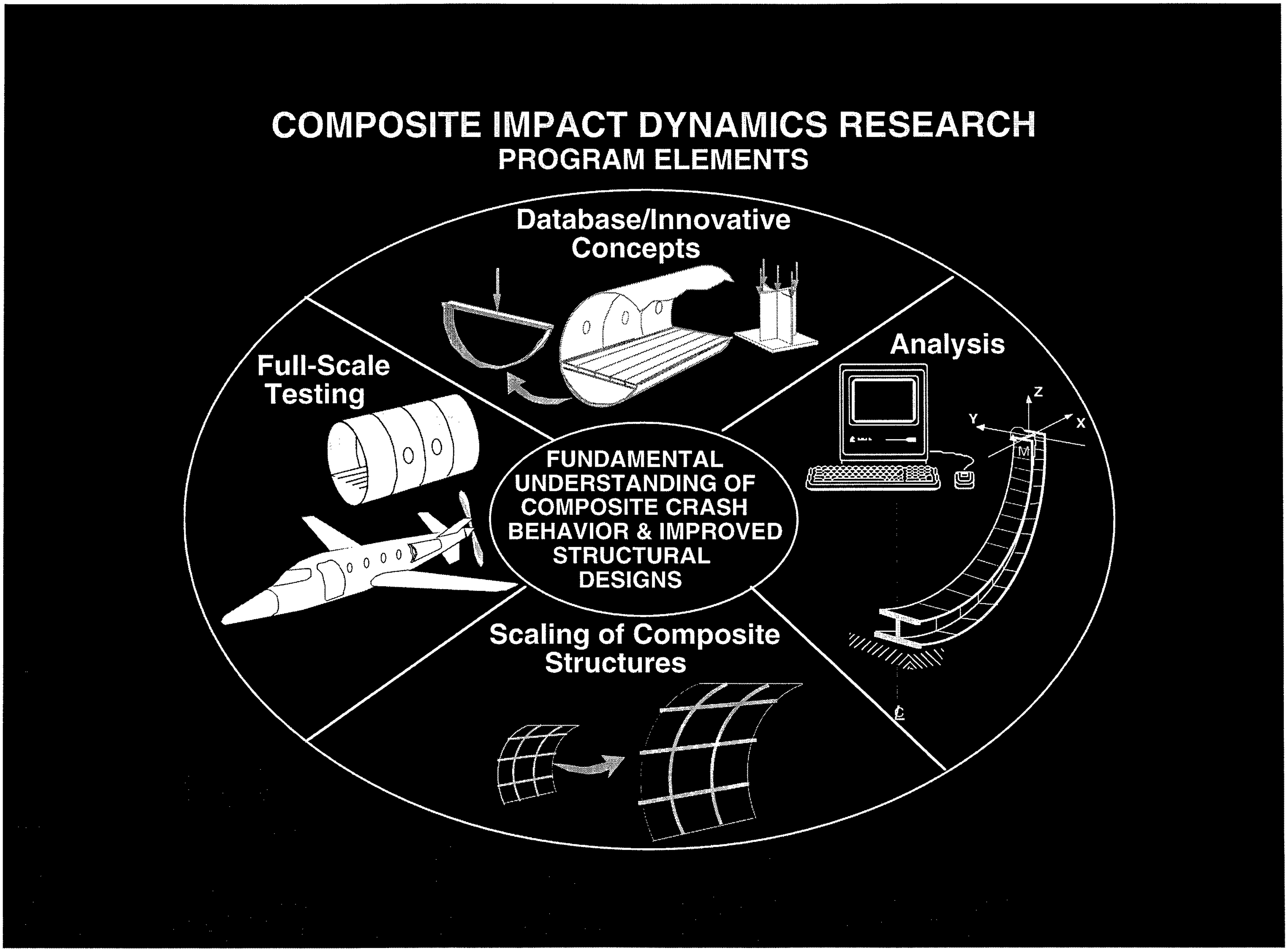
- 1970's:
  - 33 GA Aircraft Crash Tests at IDRF
  - Initiate Development of DYCAST
- 1980's:
  - Initiate Composite Crash Dynamics Research
  - CID
  - DYNA3D Code for Crash Analysis
- 1990's:
  - Crash Tests of Composite Lear Fan, Terry (Cirrus), & Starship Aircrafts
  - AGATE Program
  - Refinement of DYCAST
- 2000+:
  - ASP

1960's | 1970's | 1980's | 1990's | 2000+

Military

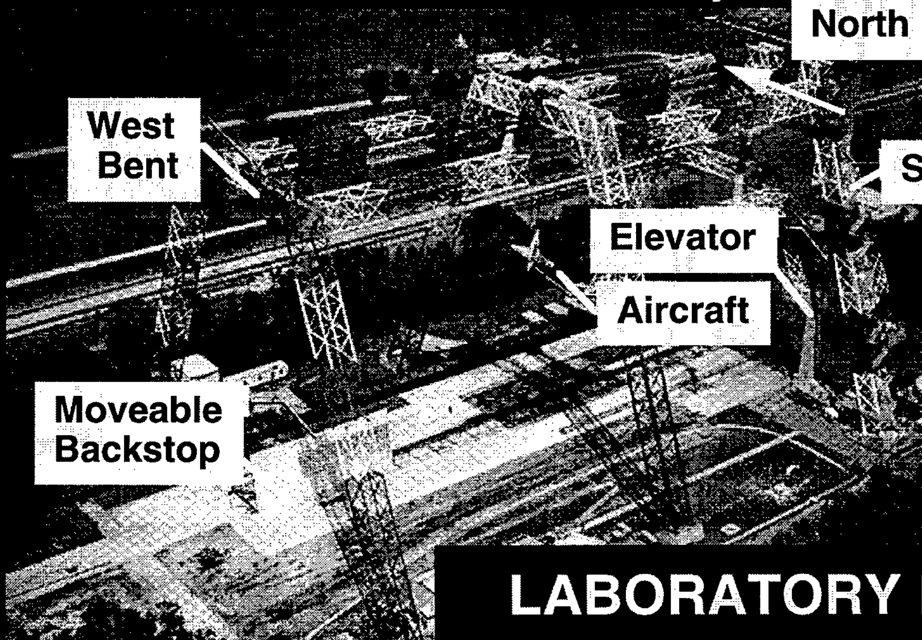
- 1960's:
  - Army Crash Mishap Studies
- 1970's:
  - MIL-STD-1290
  - Crash Survival Design Guide
  - KRASH
  - Crashworthy Fuel Systems
  - Crash Test of CH-47
- 1980's:
  - Crash Testing of UH-60, AH-64, SH-60
  - Crash of Comp. ACAP Helicopter
  - Wire Strike Protection System
- 1990's:
  - STO on Crash Analysis
  - Water Impact
  - Airbag Technology
  - Refinement of KRASH


IMPACT DYNAMICS RESEARCH
General Aviation
Metal Aircraft
B-720 Transport
Airplane (CID)
Composite
Airframe
Components
Composite Aircraft
& Rotorcraft

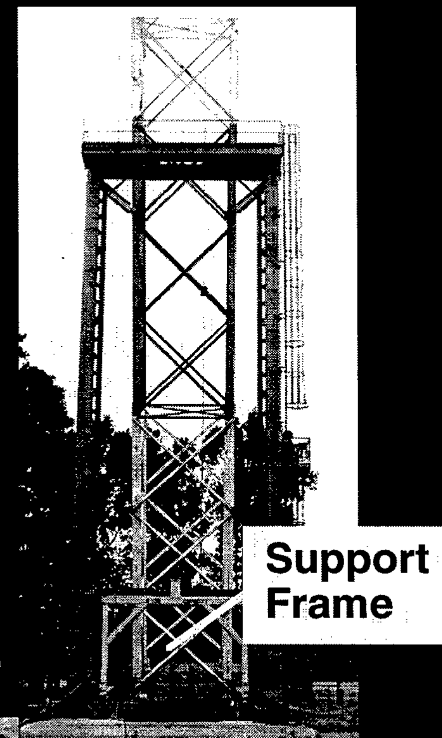

COMPOSITE IMPACT DYNAMICS RESEARCH
PROGRAM ELEMENTS
Database/Innovative Concepts
Full-Scale Testing
Analysis
FUNDAMENTAL UNDERSTANDING OF COMPOSITE CRASH BEHAVIOR & IMPROVED STRUCTURAL DESIGNS
Scaling of Composite Structures
Z
Y
X
M

CRASH DYNAMICS FACILITIES

Full-Scale Crash Facility

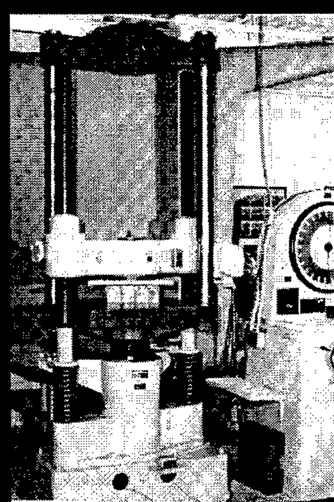


Vertical Drop Test



LABORATORY EQUIPMENT

120 Kip Static Tester



10 Kip Static Tester

Impact Tester

HUMAN SURVIVABILITY REQUIREMENTS

- MAINTAIN SURVIVABLE VOLUME
  - FUSELAGE CAGE
- RESTRAIN OCCUPANT WITHIN SURVIVABLE VOLUME
  - STANDARD RESTRAINTS
  - INFLATABLE RESTRAINTS
  - PRETENSIONERS
- LIMIT OCCUPANT LOADS
  - ENERGY ABSORBING SEATS
  - ENERGY ABSORBING SUBFLOORS
  - ANTI-PLOWING FUSELAGE STRUCTURES
  - LOAD LIMITERS & PRETENSIONERS
- MITIGATE POST-CRASH HAZARDS
  - Evacuation
  - Fire
  - Water

ENERGY ABSORBING BEAM STUDIES

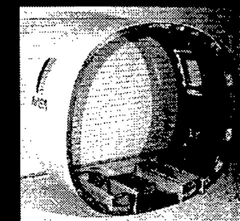
OBJECTIVES

- Design and Test Energy-Absorbing Beam Concepts For Composite Aircraft Subfloors
  - Retain integrity of flange for seat attachment
  - Retain some post crush structural integrity and stiffness
  - Produce acceptable loads transmitted to seat/occupants
  - Be readily manufactured and inexpensive as possible.
- Eventually *Retrofit* a Concept Into a Composite Airplane for Full-Scale Crash Evaluation

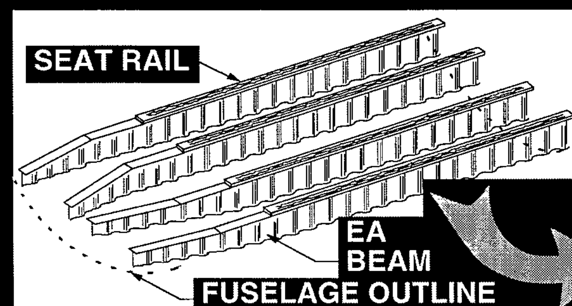
APPROACH

EA BEAMS

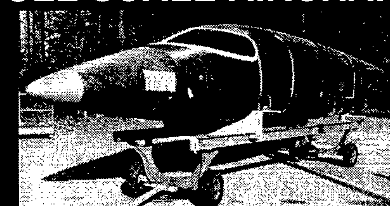
FUSELAGE SECTION



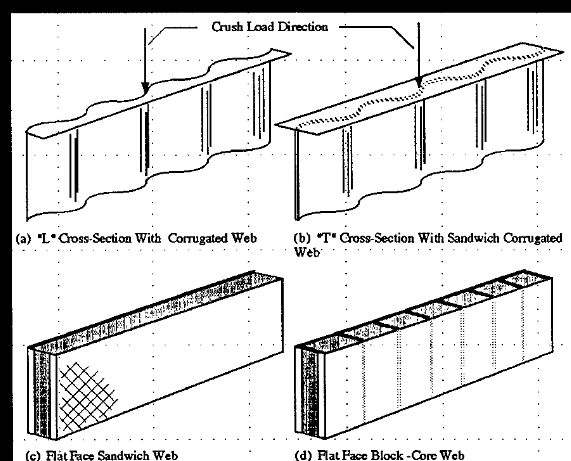
SCHEMATIC OF EA FLOOR



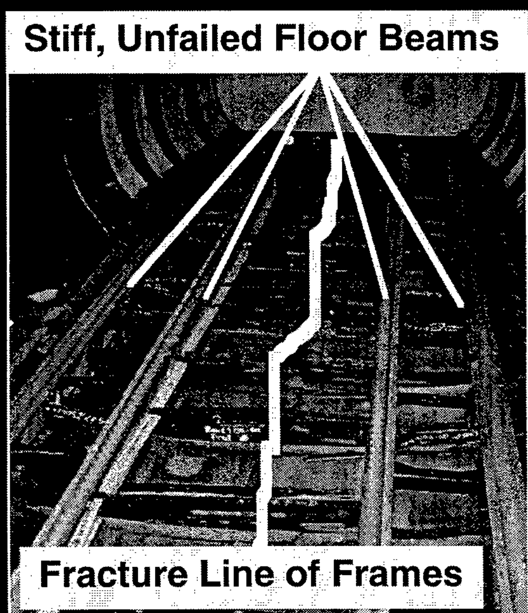
FULL-SCALE AIRCRAFT



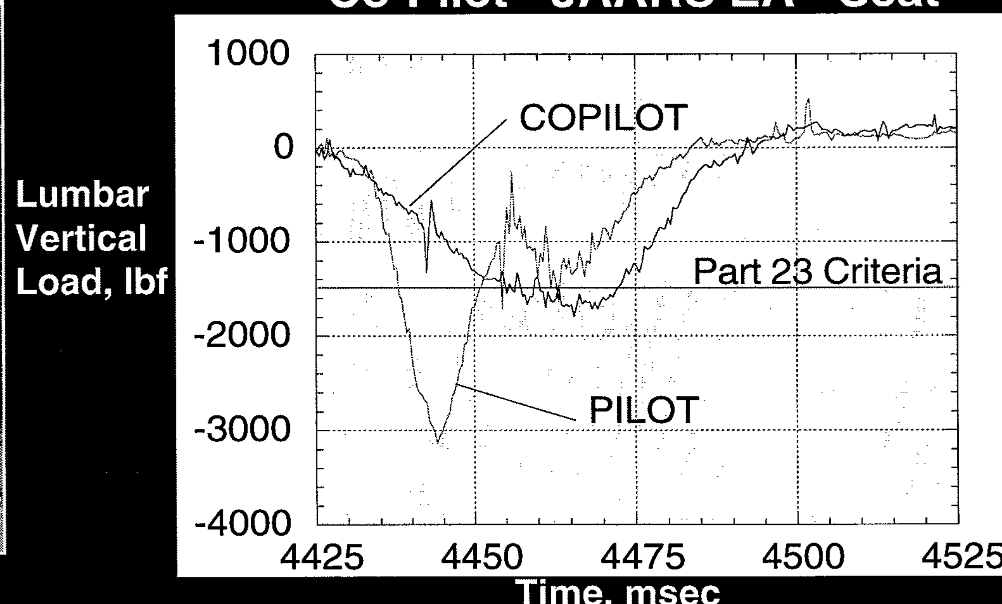
BEAM CONCEPTS



LEAR FAN COMPOSITE AIRCRAFT CRASH TEST PROVIDES IMPORTANT DATA ON STRUCTURE AND OCCUPANT LOADS



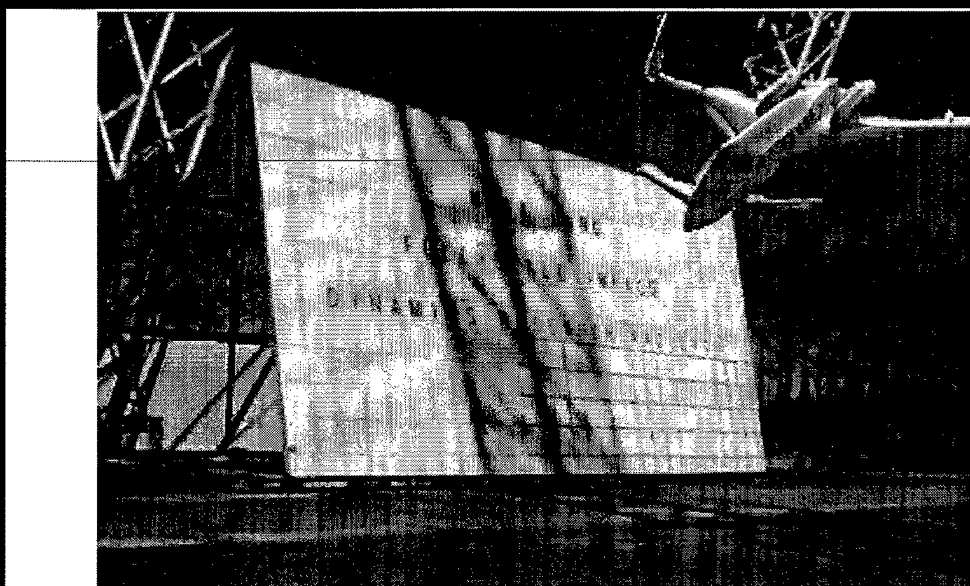
Pilot - Standard Non - EA Seat
Co-Pilot - JAARS EA - Seat

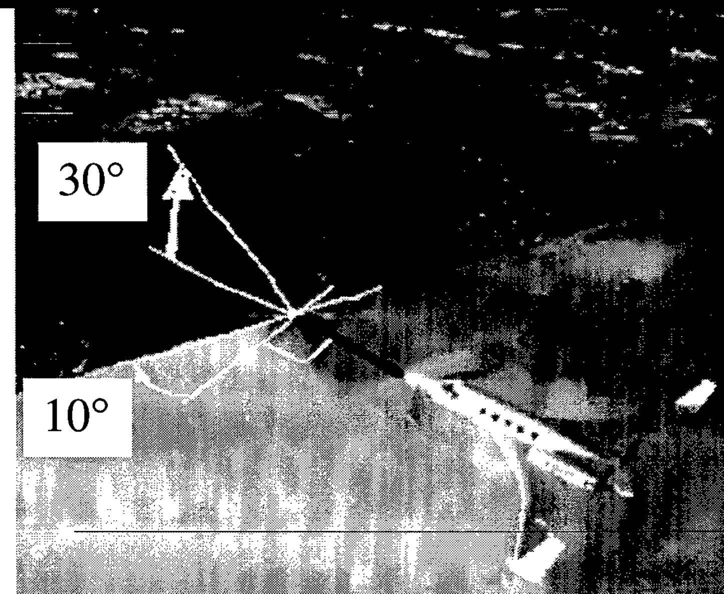


Composite Aircraft Crash Test at LaRC

Objectives:

- Add to Database of Information For Crash Behavior of Composite Aircraft Specimens (Honeycomb vs Skin-Frames)
- Specifically, Generate and Maximize Visual & Measured Crash Loads & Behavior Data for Structure, Seats, & Occupants of a Composite Aircraft During a Single Test Comprised of :
  - An Initial Impact Which Produces Primarily Vertical Loads at Part 23 Requirement of 27 fps Impact Velocity With Emphasis of Test Being Evaluation of Performance of Structure, Standard (Non-Energy Absorbing) Seats, and EA Seats, AND
  - A Secondary Impact To Produce Primarily Longitudinal Loads at Part 23 Requirement of 42 fps Velocity, With 10° Yaw on Seat/Occupants With Emphasis for Evaluation of Performance of Airbag Technology





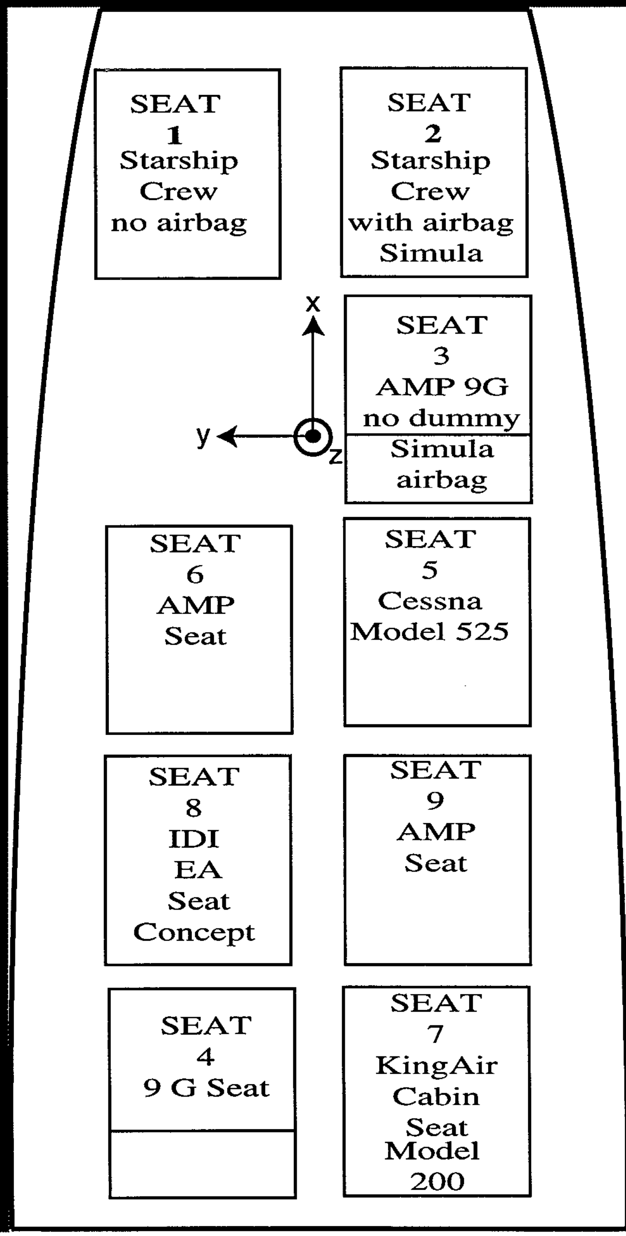
Test Parameters--Initial Vertical Impact -- Near to Prior Conditions for Comparison (Honeycomb vs Skin-Frame)

HorizontalVelocity	= 84 fps
Vertical Velocity	= 27 fps
Flight Path Angle (FPA)	= - 18°
Pitch Angle (Relative to FPA)	= 18°
Yaw & Roll Angles	= 0.0°

Test Parameters Secondary Longitudinal Impact

Horizontal Velocity	= 42 fps
Vertical Velocity	= 0.0 fps
Flight Path Angle (FPA)	= - 30°
Pitch & Roll Angle	= 0.0°
Yaw Angle	= 10°

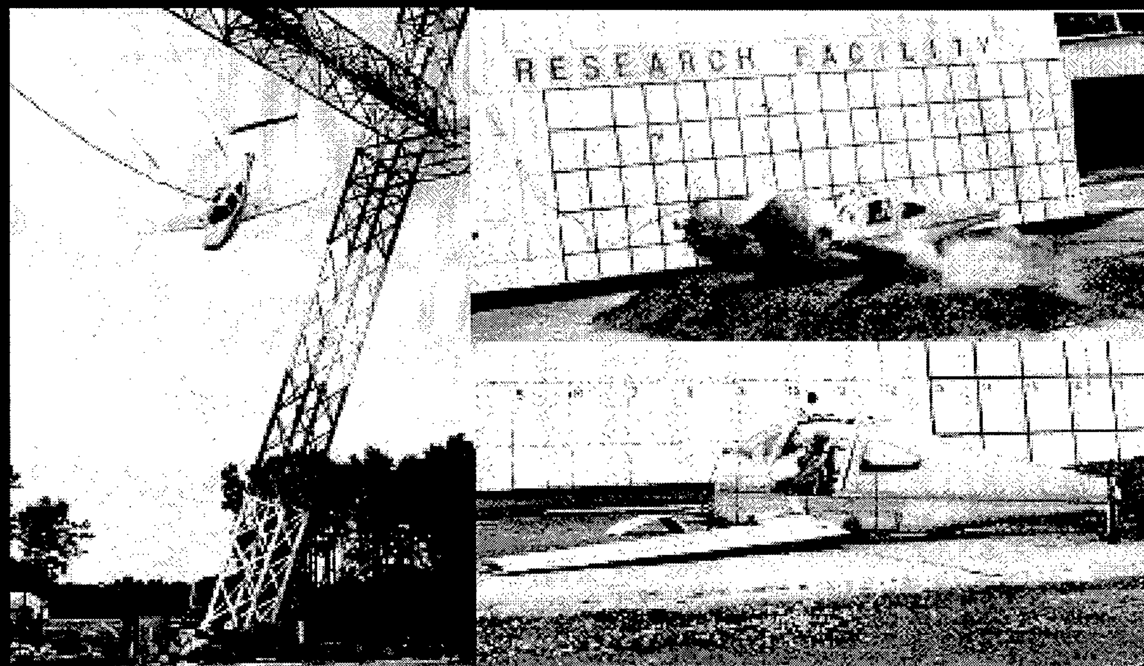
Interior Arrangement of Seats/Experiments and Typical Seat/Occupant Dummy in StarShip



Intelligent Dummy Data Acquisition System (IDDAS) Self-Contained Instrumentation (Such as shown below) was part of the data acquisition system.

Occupant dummy is in standard GA seat.

Terry Engineering Full-Scale Testing



- **Series of 4 full-scale tests**
  - 2 tests on concrete
  - 2 tests on soft soil
- **SBIR contract effort-** Data to be presented by Principal Investigator to ID&M

- **Objectives** - Systems approach to crashworthiness
  - Prevention of soil scooping
  - Improved energy absorbing seats/cushion
  - Improved restraint systems (airbags & harnesses)
  - Improved structural energy absorption and integrity

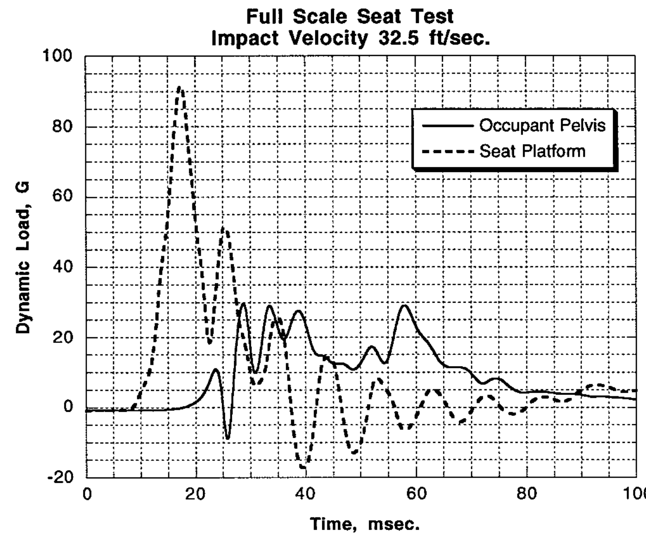
Excellent Occupant Crash Protection Achieved With an Energy Absorbing Concept Developed for "Thrush" Aircraft Seat (Ayres Corporation's Agriculture Airplane)

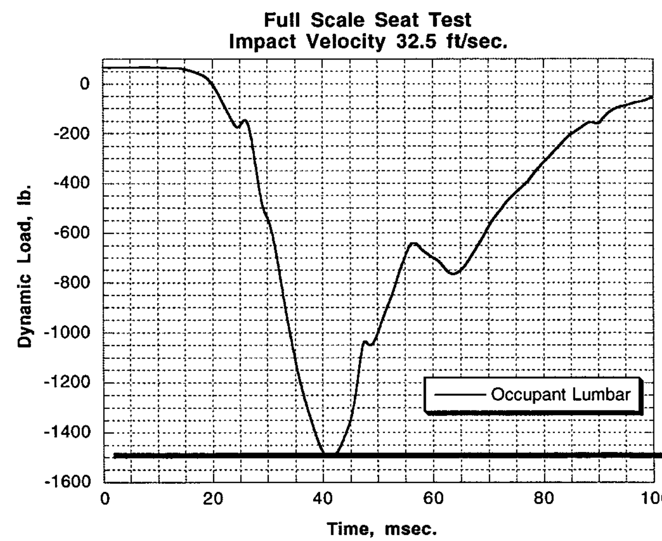
Pre-Test Seat

EA Concept

Post-Test Seat

Stroked EA Concept





1500 lbf Spinal Limit
(Part 23 Reg.)

STRUCTURAL CRASH DYNAMICS MODELING AND SIMULATION

Phase 1: Crash Code Evaluation

DRI-KRASH *DYCAST*

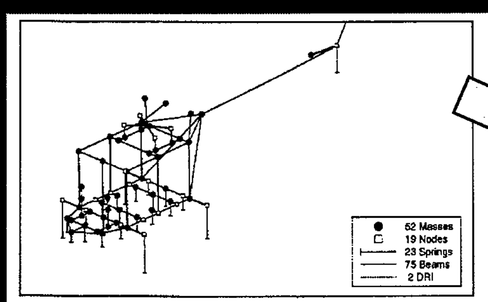
DYTRAN

LS-DYNA

DYNA3D

ABAQUS

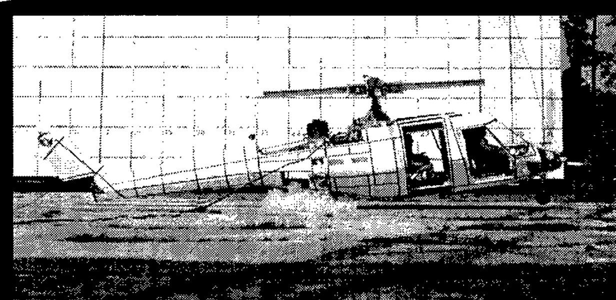
Phase 2: Crash Analysis of Composite ACAP Helicopter



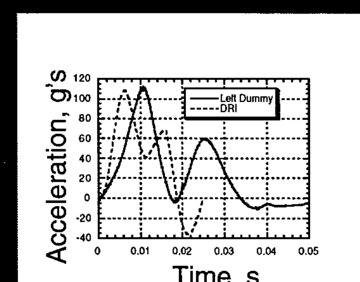
Objective:

To establish a standardized structural crash dynamics modeling and simulation capability from a single selected off-the-shelf computer code that can satisfy the need for a crashworthy performance and design evaluation tool

Phase 3: Full-Scale Crash Test of ACAP Helicopter



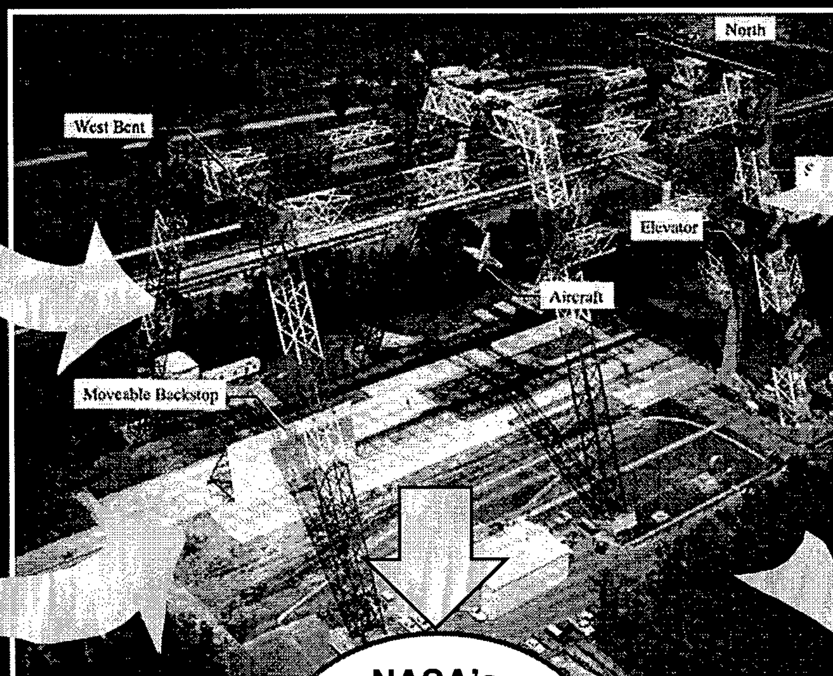
Phase 4: Validation by Analytical/Experimental Correlation



Phase 5: Code Enhancements

Research Connectivity and Coordination
Structural Crash Dynamics Modeling and Simulation

Impact Dynamics Research Facility at NASA Langley Research Center



Naval Air Warfare Center SBIR on Water Impact Criteria

Analysis Coordination

Testing

NRTC RITA Funded Research on Large Deformation Analysis (Sikorsky)

Analysis Coordination

Tech Transfer

FAA Center of Excellence for Airworthiness Assurance

Partnership Analysis

Testing

NASA's Advanced General Aviation Transport Experiment (AGATE)

Tech Transfer

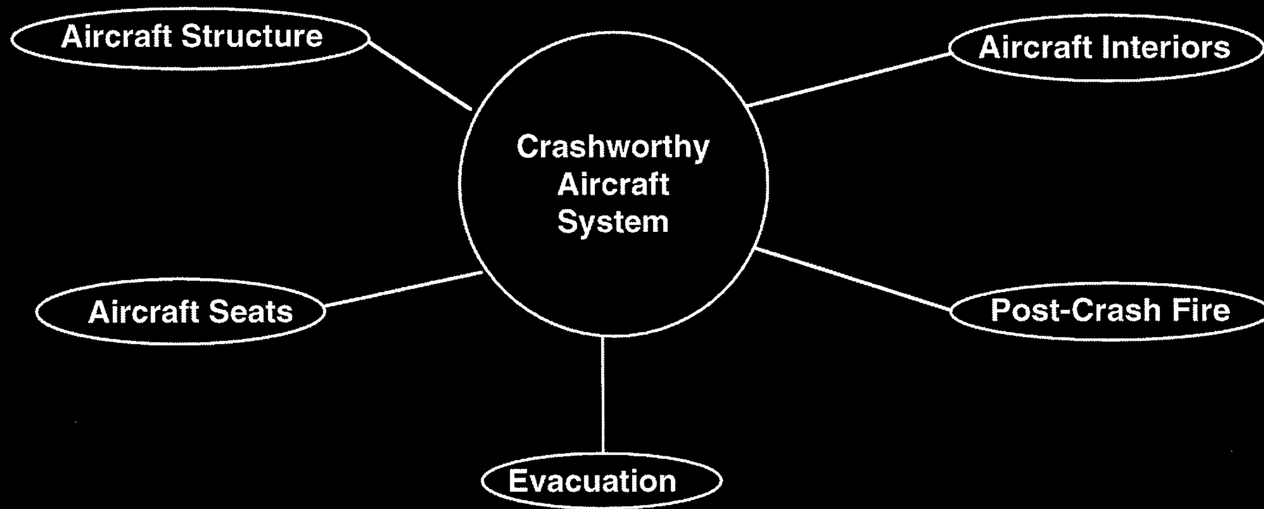
Testing

Research Coordination

NASA's Aircraft Safety Program -- Human Survivability

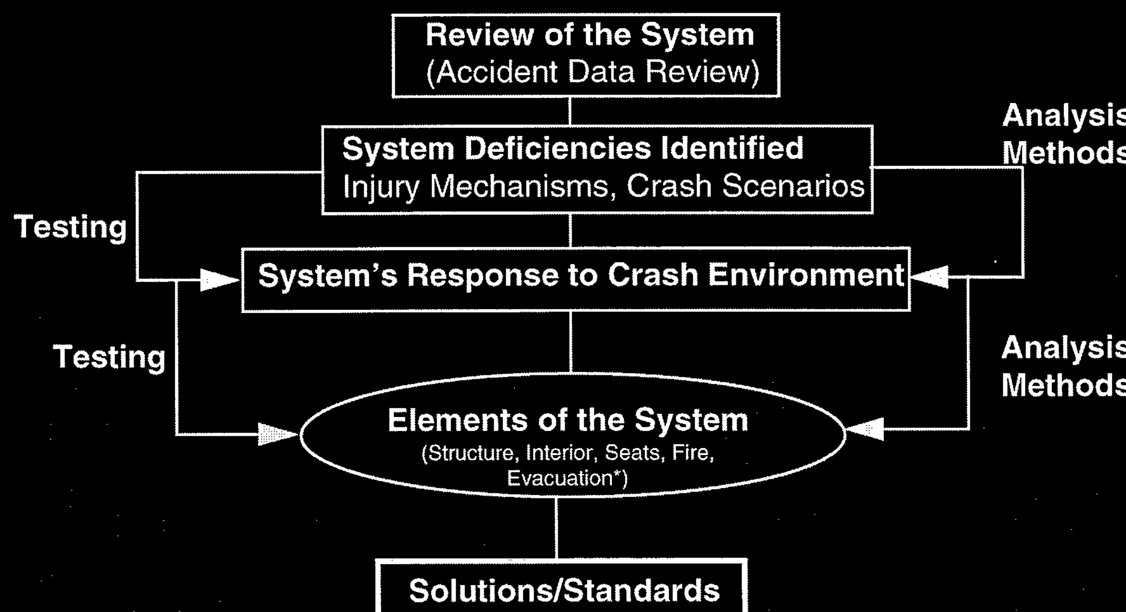
Systems Approach to Crashworthiness

Elements that Comprise the System



Why a Systems Approach ?

- **Significant Interactions Exist Between:**
  - –Occupant Response
  - –Seat Response
  - –Restraint System Performance
  - –Airframe Response
  - –Impact Surface (b.c.)
  - –Flight Conditions at Impact (i.c.)
- **Critical Needs:**
  - –Injury Criteria
  - –Component Performance
  - –Simulation Tools (Integration)



Concluding Remarks

- A Brief Review Was Given of the ASIST Process and Planning for NASA's New Aircraft Safety Program (ASP).
- During the ASIST Process, Against An Assessment of Expected Big Pay- off Areas for Reducing Fatalities and Serious Injuries In Fatal But Survivable Aircraft Accidents, The Human Survivability SubTeam :
    - Identified Four Major Focus Areas for Potential Investments Involving Survivability Initiatives.
    - Proposed A Priority List of Efforts and Allocations Within Areas.
- Planning (Both In Base and the Focused Program) Is Underway Which Supports Human Survivability Initiatives Involving Crashworthiness Technologies.
- NASA LaRC Has Been and Still Is Involved With Aircraft Research to Enhance Human Survivability Through Crashworthiness Technology.
- A Brief Review Was Given of Recent/Ongoing Crashworthiness Research at LaRC For Enhancing Human Survivability.
- Leveraging and Building on Existing Human Survivability Technology Efforts To Achieve The Aircraft Safety Program Goals Is a Strategy of The New NASA Program.